AN ASSESSMENT OF THE USE OF HISTORICAL AND RECENT AERIAL PHOTOGRAPHY TO CLASSIFY, MAP, AND CHARACTERIZE, THE CONDITIONS, AND CHANGES IN CORAL REEF HABITAT AREAS USING AERIAL PHOTOGRAPHY

NOAA ESDIM Number: NOS – '00 – 20

July 2002

Principle Investigators:
NOAA - Timothy A. Battista, Christopher D. Caldow, and Mark E. Monaco, Ph.D;
USGS - Caroline S. Rogers, Ph.D.; and
IRF - Jean-Pierre Bacle

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment

ABSTRACT

NOAA's Environmental Services Data and Information Management (ESDIM) Program sponsors projects within NOAA that meet the goals of the program in the areas of access, rescue, continuity, and innovation. ESDIM provides funding to projects which address the folowing objectives: (1) foster data quality/continuity; (2) improve and modernize access to data; (3) rescue data at risk of being irretrievably lost; and (4) encourage innovation in the process of data management. For data rescue projects it would be good to specifically identify the target audience for the data to be rescued (e.g., who would benefit) and give a brief risk assessment of the impacts of not rescuing the data.

The NOS project funded by NOAA addressed several of the primary ESDIM objectives. The project supported data rescue through the acquisition, digitization, and public internet access to historical (1961-present) NOS color aerial photography for the U.S. Virgin Islands (St. Croix, St. Thomas, and St. John); and fostered data continuity through the assessment of aerial photography to identify and map the spatio-temporal distribution of Elkhorn coral (*Acropora palmata)* in the U.S. Virgin Islands.

BACKGROUND

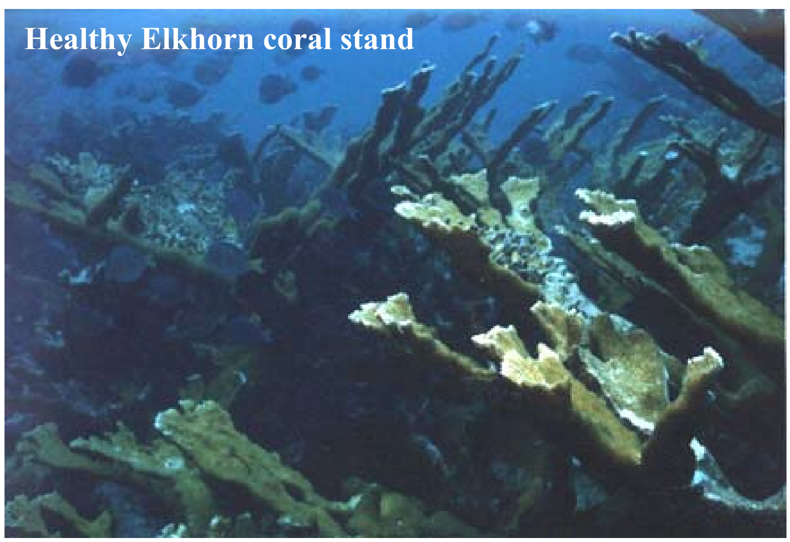
Windward reefs at depths of 1 to 5 m around St. John, St. Thomas, and St. Croix were once dominated by large colonies of the branched coral *Acropora palmata*, commonly known as Elkhorn coral. The prolific, rapid growth (5-10 cm/yr), and high structural complexity features of *A. palmata* in shallow water areas provides conditions conducive to support a more diverse fish community. Results of Lirman 1999 showed that reef sections with high coral cover and topography (i.e. Elkhorn coral) had higher overall fish abundance and species richness than areas with low cover and topography.

The precipitous decline of *A. palmata* has primarily been attributed to necrosis associated with white band disease and physical destruction from tropical storms, hurricanes, recreational boater anchor damage (Rogers 1988, Rogers et al. 1997. The prevalence of Elkhorn in shallow areas and the long flattened branches make it more susceptible to wave action. Although white band disease is not physically destructive to Elkhorn, the loss of the brown zooxanthella- bearing coral tissue leaves a dead carbonate skeleton that is either colonized by filamentous and crustose algae, or is susceptible to toppling Richardson 1998). Thus the combination of these two factors, white band disease and storm damage, have contributed to reduced live coverage of *A. palmata* by up to 80% in

many locations of the USVI (Rogers et al. 1982).

The ability to identify, map, and evaluate changes in coral reef communities has been impeded by insufficient technology to adequately delineate large coastal areas with precision, accuracy, and cost-effectiveness. The current state of knowledge of Caribbean-wide changes in reef distribution and health is limited due to inadequate studies across broad geographic areas. Although the advancement of remote sensing techniques using satellite imagery, GIS, and image analysis software may provide the means to address this critical need for benthic mapping in the foreseeable future, at the present time more-reliable alternative methods must be implemented to identify, map, and evaluate changes in coral reef communities. Currently, the only synoptic proven technology to accurately map benthic habitats through visual photo-interpretation using color aerial photography. For example, aerial photos have been used to develop digital polygons of benthic habitat distribution, via "human" interpretation techniques, for NOS's Caribbean Benthic Habitat (Kendall et al. 2002) project and to identify the incidence of white band disease in the USVI (Gladfelter 1982).

The proposed study was conducted using ESDIM funds to investigate the use of existing aerial photography from NOS and other institutions to document changes in coral reef distribution and health. The project evaluated options to develop an innovative approach to: acquire, digitize, and provide public internet access to historical (1961-present) NOS color aerial photography for the U.S. Virgin Islands (St. Croix, St. Thomas, and St. John). Furthermore, ESDIM funds were used to assess the utility of aerial photography to identify and map the spatio-temporal distribution of Elkhorn coral in the U.S. Virgin Islands. The historical photos and spatial analysis are intended to provide a valuable dataset and technique for local and state resource managers interested in conducting time-series comparison of land use and coastal change conditions in the U.S. Virgin Islands.


Healthy Elkhorn coral stand

STATEMENT OF WORK

The project contained the following two main tasks:

Task 1. Conduct a search to gather all information regarding the availability and location of recent and historical aerial photographs (e.g., NOAA, Army Corp of Engineers, NASA). Develop a database that synthesizes the metadata information collected for the available aerial photography. Where and when possible, incorporate the flight line and metadata information into a GIS to provide a spatial representation of the photograph footprint. The NOS Biogeography Program led this component.

Task 2. Evaluate the use of supervised heads-up photo-interpretation to delineate and classify areas of Elkhorn coral over time from digital georeferenced aerial photographs. The primary product of this effort will be GIS maps delineating the distribution of Elkhorn coral at five test areas located in the U.S. Virgin Islands at various time scales. These test areas (i.e., Windswept Reef, Newfound Bay, Hawksnest Bay, and Newfound Bay, St. John; and Buck Island, St. Croix) were chosen based on local expert knowledge to determine locations where large stands of Elkhorn coral were once historically present (Figure 1). This study was conducted to determine if aerial photography was a suitable remote sensing approach for conducting assessment of Elkhorn coral location and distribution. Part of the exercise was to write a methods manual that documents the project and methods used, summarizes the results of the methods evaluation, and documents the findings regarding changes in the spatial patterns of reef communities. The manual includes selected maps delineating the distribution of Elkhorn coral over time, digital aerial photography, and metadata. The manual and other selected products will be posted on our web site. The USGS led this component through contracts with IRF.

PRODUCTS

1. Historical digital aerial photography (1961 to 1992) and photography metadata has been made available on the following website for spatial querying and viewing: http://biogeo.nos.noaa.gov/products/data/photos/usvi.shtml. These data were digitally preserved from analog contact film by scanning the photographic film emulsions. These images are downloadable from the website, in addition to basic metadata information captured at the time of exposure (Frame ID, Latitude, Longitude, Height, Nominal Scale, Exposure Date).

2. A demonstration of the capabilities of the visual classification approach to assess the status and trends of changes in the distribution and health of USVI Elkhorn coral and a methods manual summarizing the results of the evaluation (See Attachment A).

CONTACTS

Dr. Mark E. Monaco
Center for Coastal Monitoring and Assessment
1305 East-West Highway, SSMC4, 9th Floor
Silver Spring, MD 20910
(301) 713-3028 x160
Mark.Monaco@noaa.gov

Timothy A. Battista
Center for Coastal Monitoring and Assessment
1305 East-West Highway, SSMC4, 9th Floor
Silver Spring, MD 20910
(301) 713-3028 x170
Tim.Battista@noaa.gov

Dr. Caroline S. Rogers
U.S. Geological Survey
P.O. Box 710
St. John, USVI 00830
(340) 693-8950
Caroline_Rogers@usgs.gov

Jean-Pierre Bacle
Island Resources Foundation
Washington, D.C. 20036
(202) 265-9712
JPBacle@irf.org

REFERENCES

Gladfelter, W.B. 1982. White-band disease in Acropora palmata: Implications for the structure and growth of shallow reefs. Bulletin of Marine Science. 32: 639-643.

Kendall, M.S., Kruer, C.R., Buja, K.R., Christensen, J.D., Finkbeiner, M. and M.E.. Monaco. 2002. Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands. National Oceanic and Atmospheric Administration. Silver Spring, MD. P. 45.

Lirman, D. 1999. Reef fish communities associated with Acropora palmata: relationships to benthic attributes. Bulletin of Marine Science. 65: 235-252.

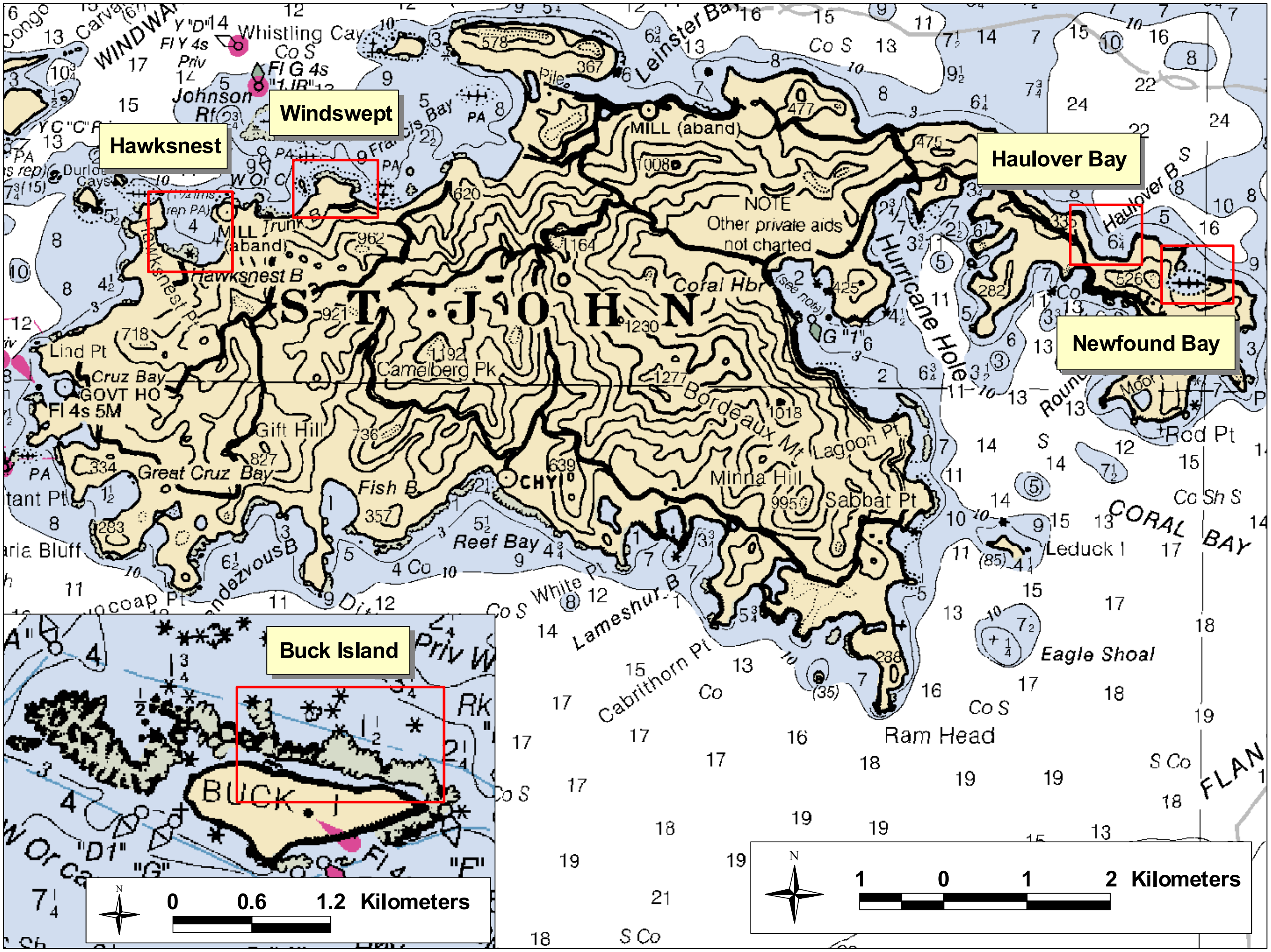
Richardson, L.L. 1998. Coral diseases: what is really known. Trends in Ecology and Evolution. 13: 438-443.

Rogers, C.S. 1988. Recommendations for long-term assessment of coral reefs: U.S. National Park Service initiates regional program. Proceedings of the 6th International Coral Reef Symposium. 2:399-403.

Rogers, C.S., Garrison, V., and R. Grober-Dunsmore. 1997. A fishery story about hurricanes and herbivory: Seven years of research on a reef in St. John, U.S. Virgin islands. Proceedings of the 8th International Coral Reef Symposium. 1:555-560.

Rogers, C.S., Suchanek, T.H., and P.H. Pecora. Effects of Hurricanes David and Frederic (1979) on shallow Acropora palmata reef communities. Bulletin of Marine Science 32:532-548.

Figure 1: *Acropora palmata* Study Areas – St. John and St. Croix, USV



Attachment A:

USE OF AERIAL PHOTOGRAPHY TO ASSESS CHANGES IN THE DISTRIBUTION OF ELKHORN CORAL IN THE U.S. VIRGIN ISLANDS

PREPARED FOR:

U.S. Geological Survey
Biological Resources Division
USGS Caribbean Field Station
St. John, U.S. Virgin Islands

PREPARED BY:

Jean-Pierre Bacle
island resources
F O U N D A T I O N
St. Thomas, U.S. Virgin Islands

September 2002

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OBJECTIVES

The main purpose of this project is to examine the feasibility of using conventional aerial photographs as a tool to document the historical and current distribution of *Acropora palmata* (Elkhorn) coral colonies. The study also attempts to document the health of *A. palmata* wherever possible. Five pre-selected "Pilot Areas" in the U.S. Virgin Islands were selected for this study. They include: Hawksnest Bay, Windswept, Haulover Bay, Newfound Bay and Buck Island (see Figures A and B in Appendix #1).

BACKGROUND

Coral reef systems at depths of 0–5m around St. John, St. Thomas and St. Croix were once dominated by large colonies of branching coral *A. palmata* commonly known as Elkhorn coral. Elkhorn coral grows rapidly (5-10cm/yr), and has a complex morphology which provide conditions conductive to support a highly diverse fish community and habitat for many other reef organisms. The rapid decline of *A. palmata* has primarily been attributed to necrosis associated with white band disease and physical destruction from tropical storms and hurricanes. The combination of these factors, white band disease and storm damage, have contributed to reductions in live coverage of *A. palmata* by up to 80% in many locations of the USVI.

METHODOLOGY

To date, one of the most cost effective technologies for mapping shallow water benthic habitats is through the use of conventional aerial photo interpretation assisted with GIS based image analysis. Aerial photographs were used to develop the Benthic Habitats of the Florida Key digital data atlas (EMRI, 1998) and just recently, a similar effort was performed for the U.S. Virgin Islands and Puerto Rico as part of the National Ocean Service's continuing effort to document coastal resources (Kendall, *et al*., 2001).

The following methodology was adapted for the specific objectives of the project. The work was broken out into five main tasks summarized as follows.

1) *Aerial Photo Selection Process*

A search to gather all information regarding the availability and location of historical and recent aerial photographs from the National Ocean Service was conducted at the onset of this study. The effort resulted in a detailed compilation of available aerial color photographs arranged according to location and date flown (see Appendix 2).

From the compiled list, selective aerial photographs for the five study sites were chosen. The selection process was based on two main criteria: optimum scale and quality of imagery. The largest scales available ranged between 1:12,000 and 1:20,000. The image quality selection process considered the amount of cloud cover, shade, sun glint, turbidity and sea state.

To evaluate changes in the *A. palmata* community through time, historical images from the 1970s were selected to compare with the most up to date coverage (1999). Coverage from the 1980s was also chosen to examine if any trend occurred between these two dates. The process resulted in a final selection as shown in the table below.

Table #1: Selected imagery for the five study sites

Study Sites	1971 1:20,000	1974 1:12,000	1977 1:20,000	1983 1:15,000	1999 1:48,000
Hawksnest Bay		●		●	●
Windswept		●		●	●
Haulover Bay	●			●	●
Newfound Bay	●			●	●
Buck Island			●		●

2) *Digital Imagery*

Aerial photos from the five study areas (1971 to 1983) were scanned with a high-resolution scanner at 1,200 dots per inch (DPI) and orthorectified. The 1999 imagery was previously scanned at 500 DPI. The georeference digital imagery output formed the basis from which the GIS Arc View 3.1 image analysis was applied.

3) *Aerial Photo Interpretation*

Conventional aerial photo interpretation with the use of a stereoscope was applied to both hard copy color imagery and diapositives (color transparencies) placed on a light table. This initial exercise allowed for an overview and establish rough delineation of fringing and barrier reef systems and preliminary assessment of *A. palmata* distribution.

4) Field Verification

Reconnaissance site visits were undertaken to validate aerial photo observations from the most current coverage (1999). Sites were visually evaluated by snorkeling and/or from the boat in shallow and clear water. Because of time and budget limitation, Buck Island was excluded.

5) Image Analysis and Mapping

Analysis and mapping was performed with the use of Arc View 3.1 that included an image analysis extension. The image analysis extension allowed for the use of a host of tools which could enhance the interpretation's accuracy and confidence level. Such tools included:

- Adjusting the brightness and contrast of the image
- Choosing band combinations
- Enhancing image display
- Applying custom histogram stretches to obtain specific visual results
- Sharpening image appearance
- Smoothing image appearance
- Using edge detection function

All mapping was conducted by using "heads-up" on-screen digitizing. Digitizing scale was done at approximately 1:2,500 to 1:3,000 for the sites. The digitized product was subsequently reduced to fit an 8.5 by 11 hardcopy presentation. A total of 16 maps were produced for the five sites (see Figures #1 to #14 in Appendix 3).

LIMITATIONS

Aerial photo interpretation with the support of GIS image analysis technology offers great potential to identify and delineate shallow water benthic communities. In this study however, we found that the interpretation's accuracy and confidence levels were ultimately linked to the scale and quality of the imagery.

Scale Limitation

Small scale imagery where ground objects appear small will have less potential to yield details. In this study, the largest scale available was 1:12,000 for only two of the selected pilot areas (see table #1). At this scale, one millimeter measured on the photographs translated to 12 meters at the ground level. Assuming that mature *A. palmata* colonies could only reach 1m to 2 m in diameter, visual recognition was deemed unreliable at this scale with identifying individual heads, however stands greater than 9 square meters could likely be identified. Increasing the scale with the GIS "zoom-in" function did little to help identify individual stands. At this small scale, the physical dimension of the *A. palmata* feature did not yield a clear signature reading (distinctive shape, pattern and color tone recognition).

Variability in scale from 1:12,000 to 1:48,000 also introduced an element of inconsistency in the mapping (digitizing) process. Since "on-screen" digitizing was done at approximately 1:2,500 for all sites, greater delineation accuracy was accomplished on the larger scale photos then the 1:48,000 coverage.

Aerial Photo Quality

Other factors limiting the accuracy of the interpretation and mapping included shadow fall, sun glint, cloud cover, turbidity and sea state. These factors were carefully considered in the process of choosing the best imagery, however, in some cases were unavoidable. For example, the 1983 coverage had significant "shadow fall" along the coastline that hindered the interpretation (see Figures #5, #8 and #11 in Appendix 3). It appears that the 1983 coverage was flown in late afternoon. That factor combined with the rugged coastline and slope aspect projected shadow falls in many sites.

Digital image quality also varied due to different scanning resolution. The ready available 1999 (1:48,000) coverage was scanned at a resolution of 500 dots per inch (DPI) while all other coverage selected for this study was scanned at 1,200 DPI resolution. The 1999 coverage with its lower scanning resolution and with its significantly smaller scale resulted in a lower image quality (fuzzier image) considered inadequate for this kind of study application.

RESULTS

Despite the severe limiting factors mentioned above, the study provided some useful information as to the distribution and relative abundance of *A. palmata*. It also provided some indication of historical trends (see Tables #1 to #5 and Figures #1 to #14 in Appendix 3).

With aerial photo interpretation combined with image analysis, it was possible to delineate the reef boundary where *A. palmata* generally occurs. These zones included the upper fore reef, the breaker zone and the reef flat.

In using the image analysis tools and the "zoom-in" function, it was possible to delineate areas densely covered with aggregate stands of *A. palmata* colonies. Distribution and abundance were estimated but with limited degree of accuracy. In most of these areas the *A. palmata* cover was intermixed with other coral species such as *Millepora sp*, *Montastrea sp* and other fragmented coral and rubble. For this reason, dense cover of *A. palmata* stands was mapped under a 60-80% cover class. Shallow reef areas covered with scattered *A. palmata* stands were mapped under the <10% class cover.

Discerning health conditions of *A. palmata* colonies such as White Band Disease (WBD) was not feasible at any scale. Identifying "standing dead" stands would be possible at a larger photo scale because shape and structure is still preserved. It was possible however to outline extensive zones that have been transformed into rubble fields due to past storms and/or areas of ongoing high energy waves constantly reworking the coral rubble. These areas usually have a high reflectance value that can be detected on the imagery.

The 5 pilot areas are described below with observations related to abundances displayed in a tabular fashion. Corresponding figures #1 to #14 are located in Appendix 3.

(1) Hawksnest Bay

Hawksnest Bay is a semi-enclosed bay and is somewhat sheltered from the normal condition of easterly wave and swell for most of the year. During the winter months, however, the northern swell is common and contributes much turbulence and wave action on the upper fore reef and beach zone.

Hawksnest has a series of shallow reefs that occupy the inner bay area. Three are narrow, elongated and extend perpendicular from the sandy beach. The fourth is situated along the eastern edge of the bay, near Gibney's beach. Total reef area is approximately 9,945m^2.

Image analysis indicates that in 1974, 11.5% of the reef areas were densely covered with *A. palmata* (60% to 80% cover). Analysis of the 1983 photos reveal a slight reduction to 10.4% and down to 5.6% by 1999 (see Table #2 and Figures #1, #2 and #3 in Appendix 3).

Table #2: Hawksnest Bay, *A. palmata* coverage

	1974 1:12,000		1983 1:15,000		1999 1:48,000	
	< 10% cover	60% - 80% cover	<10 % cover	60% - 80% cover	<10% cover	60% - 80% cover
Reef Area 1 3,748 m^2	734m^2	362m^2	35m^2	426m^2		385m^2
Reef Area 2 3,653 m^2	694m^2	536m^2	75m^2	448m^2	534m^2	270m^2
Reef Area 3 1,121 m^2		130m^2	51m^2		108m^2	
Reef Area 4 1,423 m^2		111m^2	75m^2	160m^2	132m^2	
Total 9,945 m^2	**1,428 m^2 (14.3%)**	**1,139 m^2 (11.5%)**	**236 m^2 (2.3%)**	**1,034 m^2 (10.4%)**	**774 m^2 (7.7%)**	**566 m^2 (5.6%)**

(2) Windswept

Windswept is located immediately east of Trunk Bay. The area can be characterized as an exposed rocky headland fronted by a large fringing reef system. The area is protected from easterly currents by Mary's Point. During the winter months the northern swell causes breaking waves on the reef.

The fringing reef can be subdivided into four areas, the larger ones separated by distinctive sand channels. The total reef system covers about 39,735 m^2. From the 1974 imagery, it is estimated that dense *A. palmata* areas (60% to80%) occupied 9.5% of the total reef area. In 1983, the dense cover was reduced to 3% and increased back to 6.4% by 1999 (see Table #4 and Figures #4, #5 and #6). The significant decrease in 1983 is partially due to poor image quality as a result of shadow fall obstructing the interpretation (see Figure #5).

Table #3: Windswept, *A. palmata* coverage

	1974 1:12,000		1983 1:15,000		1999 1:48,000	
	<10% cover	60%-80% cover	<10%cover	60%-80% cover	<10%cover	60%-80% cover
Reef Area 1 11,550 m^2	3,928m^2	213m^2	3,842m^2	N/A	3,524m^2	571m^2
Reef Area 2 19,185 m^2	5,253m^2	2,144m^2	3,219m^2	821m^2	4,410m^2	1,078m^2
Reef Area 3 3,500 m^2	1,273m^2	178m^2	1,389m^2	N/A	1,110m^2	152qm^2
Reef Area 4 5,500 m^2	1,103m^2	1,264m^2	1,273m^2	360m^2	842m^2	751m^2
Total 39,735 m^2	**11,557 m^2 (29.0%)**	**3,799 m^2 (9.5%)**	**9,723 m^2 (24.4%)**	**1,181 m^2 (2.9%)**	**9,886 m^2 (24.8%)**	**2,552 m^2 (6.4%)**

(3) Haulover Bay

Haulover Bay is a large, partially exposed bay of greater depth. The image analysis was limited to the western side of the bay which is within the park boundary. The eastern portion of the bay is predominantly subtidal bedrock.

The western reef system is breached in two by a narrow sand channel. The combined reef area cover is 15,650 m^2. Analysis of the 1971 imagery estimate extensive *A. palmata* thickets (60% to80%) covered about 26% of the reef area. The recent 1999 imagery revealed that dense cover has completely disappeared (see Table #4 and Figures 7,8 and 9). Area #1 in Figure #8 is not shown due to a wrong frame selection.

Table #4: Haulover Bay, *A. palmata* cover

	1971 1:20,000		1983 1:15,000		1999 1:48,000	
	<10% cover	60%-80% cover	<10% cover	60%-80% cover	<10% cover	60%-80% cover
Reef Area 1 10,696 m^2	8,013m^2	2,683m^2	Incomplete Image	Incomplete Image	1980m	0
Reef Area 2 4,954 m^2	3,583m^2	1,371m^2	3,842m^2	1,112m^2	0	0
Total 15,650 m^2	**11,596 m^2 (74%)**	**4,054 m^2 (26%)**	**3,842 m^2 (24.5%)**	**1,112 m^2 (7.1%)**	**1980 m^2 (12.6%)**	**0**

(4) Newfound Bay

Located in the east end of St John along the north shore, Newfound Bay benefits from the sheltering effect of a partially closed bay mouth barrier reef system. Since 1971, the exposed reef system has suffered significant decline in live coral including *A. palmata*. In 1971 it is estimated that 16% of this reef was densely covered (60% to 80%). By 1983, densely covered areas were reduced to a little over 9% of the reef area. Imagery from 1999 show no aggregate stands, only sparse occurrences (see Table #5 and Figures #10, #11 and #12).

Figures #12a and #12b represent examples of selective image analysis tools that were used in the interpretation.

Despite the obvious wipeout, field reconnaissance during 2002 revealed numerous individual stands of young colonies sprouting all along the reef crest and upper fore reef. Most of the stands were estimated at 30cm in diameter.

Table #5: Newfound Bay, *A. palmata* cover

	1971 1:20,000		1983 1:15,000		1999 1:48,000	
	<10% cover	60%-80% cover	<10% cover	60%-80% cover	<10% cover	60%-80% cover
Reef Area 1 8,258 m^2	6,906m^2	1,352m^2	7,332m^2	926m^2	155m^2	none
Reef Area 2 13,635 m^2	10,453m^2	2,182m^2	12,583m^2	1,052m^2	none	none
Total 21,893 m^2	**17,359 m^2 (79.2%)**	**3,534 m^2 (16.1%)**	**19,915 m^2 (90.9%)**	**1,978 m^2 (9.0%)**	**155 m^2 (0.7%)**	**none**

(5) Buck Island

Buck Island is located 2 km north of Teague Bay, St Croix. The study area includes the barrier reef that wraps around the eastern tip of the island and is situated approximately 200-250 m from the shoreline. The location and structure of this barrier reef forms an arc that protects Buck Island from the dominant easterly wave attack.

The study area is limited to the shallow portion of the barrier reef, namely the reef crest, upper fore reef and adjoining back reef. It is segmented into seven reef areas forming a total of 113,974 m^2. Aerial photo analysis indicates that in 1977, 30.6% of the study area was densely covered with *A. palmata* thickets (60% to 80% cover). Recent 1999 imagery reveals a dramatic decline in that only 9.2% of the study area has very sparse (<10%) occurrences of *A. palmata* cover (see Table #6 and Figures #13 and #14).

No photo coverage was available from the 1980s.

Table #6: Buck Island, *A. palmata* cover

	1977 (1:20,000)	1999 (1:48,000)
	60%-80% cover	<10% cover
Reef Area 1 1,220m^2	315m^2	231m^2
Reef Area 2 8,595m^2	1,301m^2	999m^2
Reef Area 3 3,450m^2	1,014m^2	885m^2
Reef Area 4 7,330m^2	1,780m^2	1,397m^2
Reef Area 5 7,486m^2	2,875m^2	2,445m^2
Reef Area 6 77,430m^2	25,300m^2	3,583m^2
Reef Area 7 8,463m^2	2,367m^2	923m^2
Total: 113,974m^2	**34,952m^2 (30.6%)**	**10,464m^2 (9.2%)**

REMARKS & RECOMMENDATIONS

Aerial photo interpretation has proven to be a useful tool to define and delineate benthic habitat. Limits in the accuracy of the interpretation do exist and are usually attributed to the scale and quality of the image as well as resolution lost due to the scanning process. It's also important to note that the success in carrying out the aerial photo interpretation exercise depends in large measure on prior training and experience of the interpreter in the discipline relevant to the problem in question. Thus, it's reasonable to expect that no two interpreters will produce the exact same results.

This study concludes that identifying individual *A. palmata* colonies is not possible from the aerial photos available even with the aid of a GIS "zoom-in" function and analysis tools. The aerial photo scales are considered too small for this type of application.

Furthermore, variability in scale from historical coverage to present is considerable and creates inherent inconsistencies in the interpretation process.

It is possible however to interpret and delineate extensive, densely aggregated stands of *A. palmata* with a moderate level of accuracy. A classification cover of (60% to 80% cover) was set to better reflect densely aggregate stands of *A. palmata* cover. It is important to note that such areas also include other coral species in the mix such as *Millepora sp* and *Montastrea sp* as well as variable quantities of fragmented and dead coral. As a result, this study should be considered more as a qualitative assessment rather then a quantitative one.

To better meet the objectives of such a study, acquisition of large scale photography is a prerequisite. Minimum aerial photo scale should be at least 1:500, meaning that one millimeter (mm) measured on the aerial photo translates to 0.5m on the ground. Form, structure and signature tone of individual *A. palmata* stands could be identified at that scale and perhaps its health status also.

The cost benefit for such a study remains to be determined. The very first priority should focus on designing a list of specifications tailored specifically for this kind of application. Priority considerations should be on low altitude large scale imagery and optimum image type. Conventional color is adequate, however other image types should be reviewed such as the Compact Airborne Spectrographic Imager (CASI) system. It was recently reported that using this special digital sensor system on a plane flying at 250 meters above sea level helped diagnose more comprehensively the health status of reefs (Raloff, 2001).

ACKNOWLEDGEMENTS

The following persons were instrumental in providing technical support and guidance:

Dr. Caroline Rogers, U.S. Geological Survey

Dr. Barry Devine, Center for Data Conservation, University of the U.S. Virgin Islands

Tim Battista, NOAA National Ocean Service
Dr. Marc Monaco, NOAA National Ocean Service
Matt Kendall, NOAA National Ocean Service
Ken Buja, NOAA National Ocean Service
Lita Katz, NOAA National Ocean Service
Marilyn King, NOAA National Ocean Service

REFERENCES

Anderson, M., Lund, H., Gladfelter, E., and M. Davis. 1986. Ecological community type maps and biological descriptions for the Buck Island Reef National Monument and proposed marine sites in the British Virgin Islands. Biosphere Reserve Report Number 4, National Park Service, Dept. of Interior. 235pp.

Bacle, J.P. 1995. Mapping coastal habitat features Great Pond Bay, St. Croix. U.S. Virgin Islands. *Photo Interpretation*. 4:264-268.

Beets, J., L. Leewand, and E.S. Zullo. 1986. Marine community descriptions and maps of the bays within the Virgin Islands National Park/Biosphere Reserve. Biosphere Reserve Research Report Number 2, National Park Service, Dept. of Interior. 118pp.

Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute (FMRI) and National Ocean and Atmospheric Administration. 1998. Benthic Habitats of the Florida Keys. FMRI Technical Report No. TR-4. 52pp.

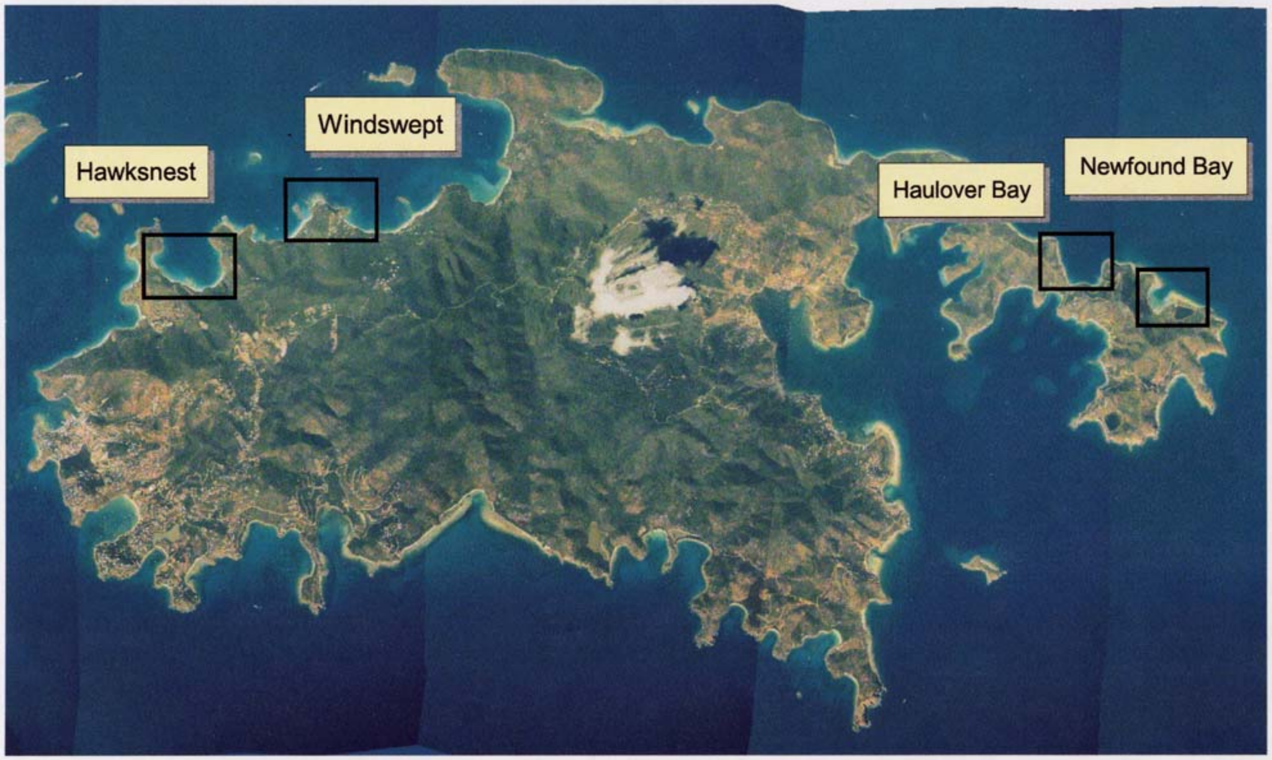
Kendall, M.S., C.R. Kruer, K.R. Buja, J.D. Christensen, M. Finkbeiner, and M.E. Monaco. 2001. NOAA Technical Memorandum NOS NCCOS CCMA 152. Methods used to map the benthic habitats of Puerto Rico and the U.S. Virgin Islands. 45pp.

Raloff, J., 2001. Aircraft spies on health of coral reefs. *Science News*, Vol.160, No.10.

Rogers, C., 2000. Is *Acropora palmata* (Elkhorn coral) making a comeback in the Virgin Islands? *Reef Encounter* 27, July.

Appendix 1:

Figure A: Acropora palmata / Study Areas / St. John



Source: 1999 Airphoto mosaic / NOAA

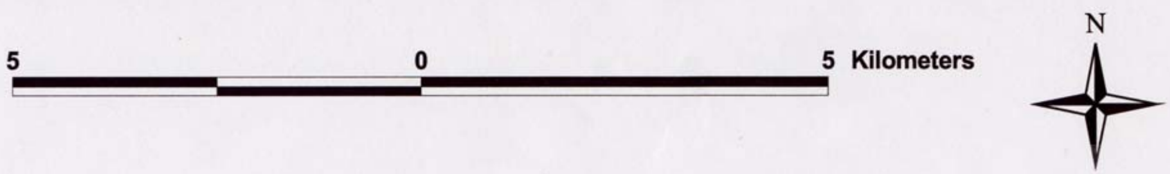
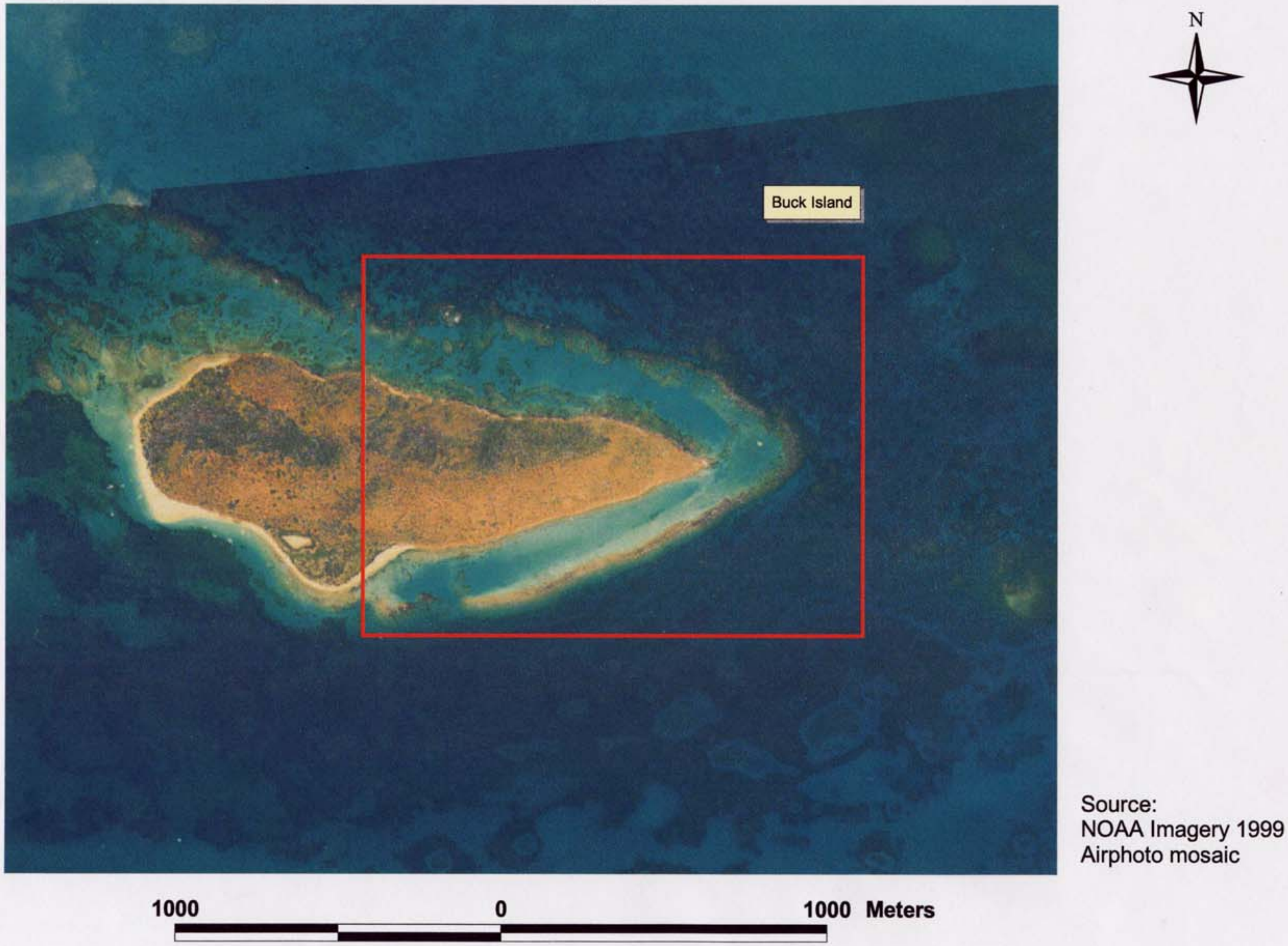


Figure B: Acropora palmata Study Area / St. Croix, U.S.V.I.



Appendix 2: Aerial Photo Compilation

Roll No.	Photo	Scale	Date	Map Index No.	Area Covered	Quality	incomplete	glint	shade	clouds	turbidity
100-720	846	1:30k	11/15/1971	PR3-4	Windswept	A					
100-720	847	1:30k	11/15/1971	PR3-4	Hawksnest	A					
100-720	847	1:30k	11/15/1971	PR3-4	Windswept	A					
100-720	848	1:30k	11/15/1971	PR3-4	Hawksnest	A					
100-720	848	1:30k	11/15/1971	PR3-4	Windswept	C		X			
100-720	889	1:30k	11/15/1971	PR3-4	Hawksnest	B				X	
100-720	889	1:30k	11/15/1971	PR3-4	Windswept	A					
100-720	890	1:30k	11/15/1971	PR3-4	Hawksnest	B				X	
100-720	890	1:30k	11/15/1971	PR3-4	Windswept	A					
100-720	891	1:30k	11/15/1971	PR3-4	Windswept	A					
100-720	893	1:30k	11/15/1971	PR3-4	Haulover	B		X			
100-720	893	1:30k	11/15/1971	PR3-4	Newfound	B		X			
100-720	894	1:30k	11/15/1971	PR3-4	Haulover	B		X			
100-720	894	1:30k	11/15/1971	PR3-4	Newfound	B		X			
100-720	895	1:30k	11/15/1971	PR3-4	Haulover	A		X			
100-720	895	1:30k	11/15/1971	PR3-4	Newfound	A		X			
100-720	897	1:30k	11/15/1971	PR3-4	Windswept	B				X	
100-720	898	1:30k	11/15/1971	PR3-4	Hawksnest	A					
100-720	898	1:30k	11/15/1971	PR3-4	Windswept	A				X	
100-720	899	1:30k	11/15/1971	PR3-4	Hawksnest	B		X			
100-720	899	1:30k	11/15/1971	PR3-4	Windswept	B		X			
100-720	914	1:30k	11/15/1971	PR3-4	Haulover	C	X		X	X	
100-720	915	1:30k	11/15/1971	PR3-4	Haulover	C	X	X	X		
100-720	915	1:30k	11/15/1971	PR3-4	Newfound	A				X	
100-721	966	1:20k	11/15/1971	PR3-3	Hawksnest	C	X	X			
100-721	966	1:20k	11/15/1971	PR3-3	Windswept	C		X		X	
100-721	967	1:20k	11/15/1971	PR3-3	Hawksnest	C	X	X			
100-721	967	1:20k	11/15/1971	PR3-3	Windswept	C		X			
100-721	1000	1:30k	11/20/1971	PR3-4	None	X					

Roll No.	Photo	Scale	Date	Map Index No.	Area Covered	Quality	incomplete	glint	shade	clouds	turbidity
100-721	1001	1:30k	11/20/1971	PR3-4	Haulover	C	X		X		
100-721	1001	1:30k	11/20/1971	PR3-4	Newfound	A					
100-721	1002	1:30k	11/20/1971	PR3-4	Haulover	A					
100-721	1002	1:30k	11/20/1971	PR3-4	Newfound	B		X			
100-721	1003	1:30k	11/20/1971	PR3-4	Haulover	A					
100-721	1003	1:30k	11/20/1971	PR3-4	Newfound	B		X	X		
100-721	1031	1:30k	11/20/1971	PR3-4	Hawksnest	A					
100-721	1031	1:30k	11/20/1971	PR3-4	Windswept	A					
100-721	1032	1:30k	11/20/1971	PR3-4	Hawksnest	A					
100-721	1032	1:30k	11/20/1971	PR3-4	Windswept	A					
100-721	1033	1:30k	11/20/1971	PR3-4	Windswept	A					
100-721	1035	1:30k	11/20/1971	PR3-4	Haulover	A					
100-721	1035	1:30k	11/20/1971	PR3-4	Newfound	B		X			
100-721	1036	1:30k	11/20/1971	PR3-4	Haulover	A					
100-721	1036	1:30k	11/20/1971	PR3-4	Newfound	A		X			
100-721	1037	1:30k	11/20/1971	PR3-4	None	X					
100-721	1045	1:20k	11/20/1971	PR3-3	Haulover	A			X		
100-721	1046	1:20k	11/20/1971	PR3-3	Haulover	A		X			
100-721	1052	1:20k	11/20/1971	PR3-3	Haulover	A		X			
100-721	1052	1:20k	11/20/1971	PR3-3	Newfound	C		X			
100-721	1053	1:20k	11/20/1971	PR3-3	Haulover	A					
100-721	1053	1:20k	11/20/1971	PR3-3	Newfound	A		X			
100-721	1054	1:20k	11/20/1971	PR3-3	Newfound	A					
100-722	1123	1:30k	11/20/1971	PR3-3	Buck	B	X				
100-722	1124	1:30k	11/20/1971	PR3-3	Buck	A	X				
100-722	1125	1:30k	11/20/1971	PR3-3	Buck	B	X				
100-823	7014	1:12k	2/11/1974	PR3-6	Hawksnest	B	X				
100-823	7015	1:12k	2/11/1974	PR3-6	Hawksnest	A					
100-823	7016	1:12k	2/11/1974	PR3-6	Hawksnest	A					
100-824	7103	1:12k	2/12/1974	PR3-6	Hawksnest	A					

Roll No.	Photo	Scale	Date	Map Index No.	Area Covered	Quality	incomplete	glint	shade	clouds	turbidity
100-824	7104	1:12k	2/12/1974	PR3-6	Hawksnest	A					
100-824	7111	1:12k	2/12/1974	PR3-6	Windswept	A					
100-824	7112	1:12k	2/12/1974	PR3-6	Windswept	A					
100-824	7113	1:12k	2/12/1974	PR3-6	Hawksnest	A					
100-824	7113	1:12k	2/12/1974	PR3-6	Windswept	B	X				
100-824	7114	1:12k	2/12/1974	PR3-6	Hawksnest	A					
100-824	7115	1:12k	2/12/1974	PR3-6	Hawksnest	A	X				
100-985	9114	1:20k	11/14/1977	PR3-10	Buck	C	X				X
100-985	9115	1:20k	11/14/1977	PR3-10	Buck	C	X				X
100-985	9116	1:20k	11/14/1977	PR3-10	None	X					
100-985	9170	1:20k	11/14/1977	PR3-10	Buck	B	X				X
100-985	9171	1:20k	11/14/1977	PR3-10	Buck	B					X
100-985	9172	1:20k	11/14/1977	PR3-10	Buck	B	X				X
100-991	5597	1:30k	11/30/1977	PR3-9	Buck	B	X				
100-991	5598	1:30k	11/30/1977	PR3-9	Buck	B	X				
100-991	5599	1:30k	11/30/1977	PR3-9	Buck	B	X				
100-991	5616	1:30k	12/3/1977	PR3-9	Buck	B	X				
100-991	5617	1:30k	12/3/1977	PR3-9	Buck	B	X				
100-993	9894	1:20k	12/7/1977	PR3-10	Buck	B	X	X			
100-993	9895	1:20k	12/7/1977	PR3-10	Buck	B		X			
100-993	9896	1:20k	12/7/1977	PR3-10	Buck	B		X			
100-993	9897	1:20k	12/7/1977	PR3-10	Buck	B	X	X			
100-993	9898	1:20k	12/7/1977	PR3-10	Buck	B	X				
200-221	2129	1:30k	3/25/1983	PR2-3	Hawksnest	A					
200-221	2129	1:30k	3/25/1983	PR2-3	Windswept	A					
200-221	2130	1:30k	3/25/1983	PR2-3	Hawksnest	B		X			
200-221	2130	1:30k	3/25/1983	PR2-3	Windswept	A					
200-221	2137	1:30k	3/25/1983	PR2-3	Haulover	A					
200-221	2137	1:30k	3/25/1983	PR2-3	Newfound	A					
200-232	2249	1:15k	3/25/1983	PR2-3	Newfound	A			X		

Roll No.	Photo	Scale	Date	Map Index No.	Area Covered	Quality	incomplete	glint	shade	clouds	turbidity
200-232	2250	1:15k	3/25/1983	PR2-3	Haulover	B	X		X		
200-232	2250	1:15k	3/25/1983	PR2-3	Newfound	A			X		
200-232	2251	1:15k	3/25/1983	PR2-3	Haulover	B			X		
200-232	2251	1:15k	3/25/1983	PR2-3	Newfound	A			X		
200-232	2285	1:15k	3/25/1983	PR2-3	Hawksnest	A			X		
200-232	2285	1:15k	3/25/1983	PR2-3	Windswept	A					
200-232	2286	1:15k	3/25/1983	PR2-3	Hawksnest	A			X		
200-232	2286	1:15k	3/25/1983	PR2-3	Windswept	A					
200-569	7204	1:20k	1992	MapFinder	Buck	C	X				
200-569	7205	1:20k	1992	MapFinder	Buck	C	X				

Figure #2: St. John / Hawksnest /1983

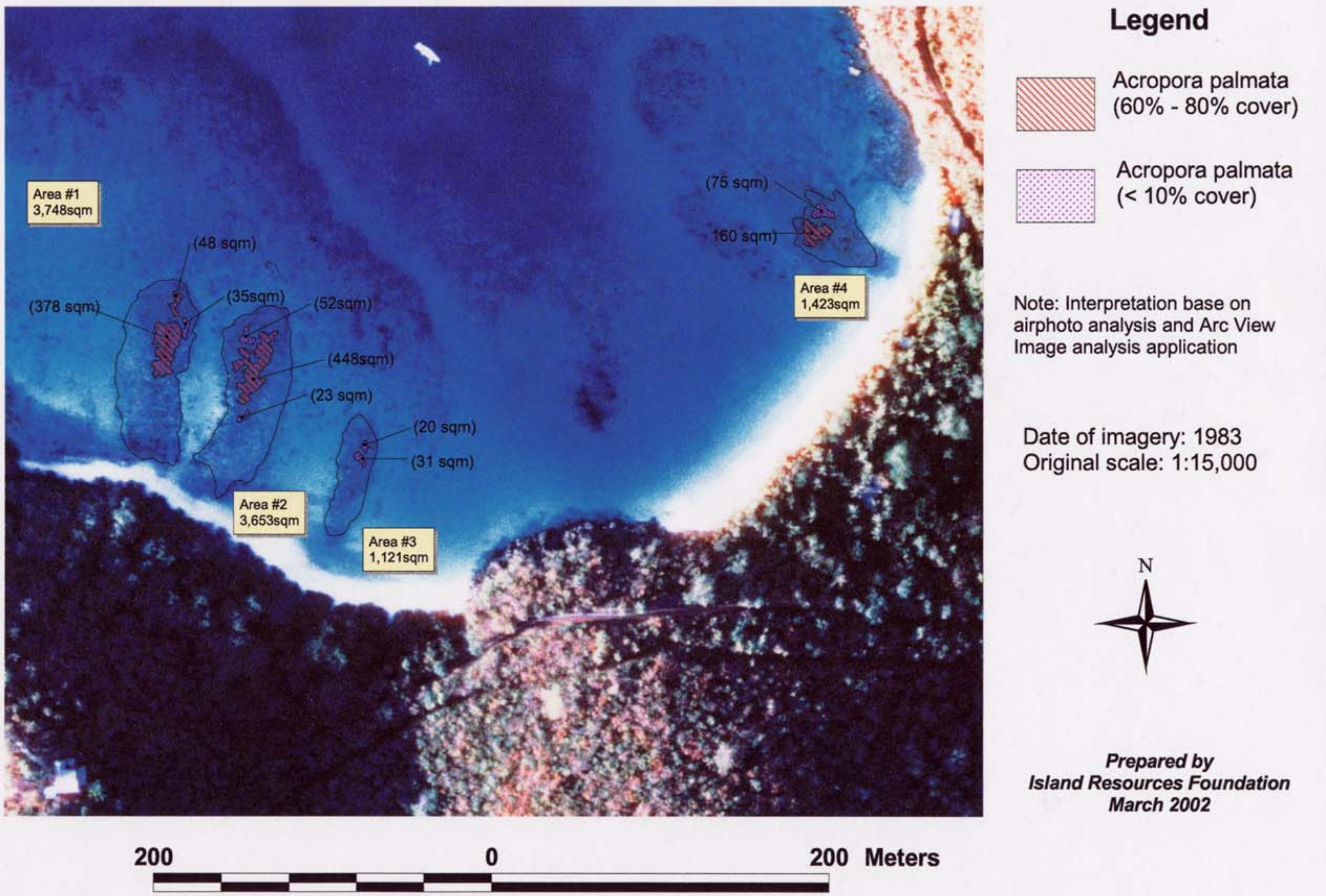


Figure #3: St. John / Hawksnest Bay / 1999

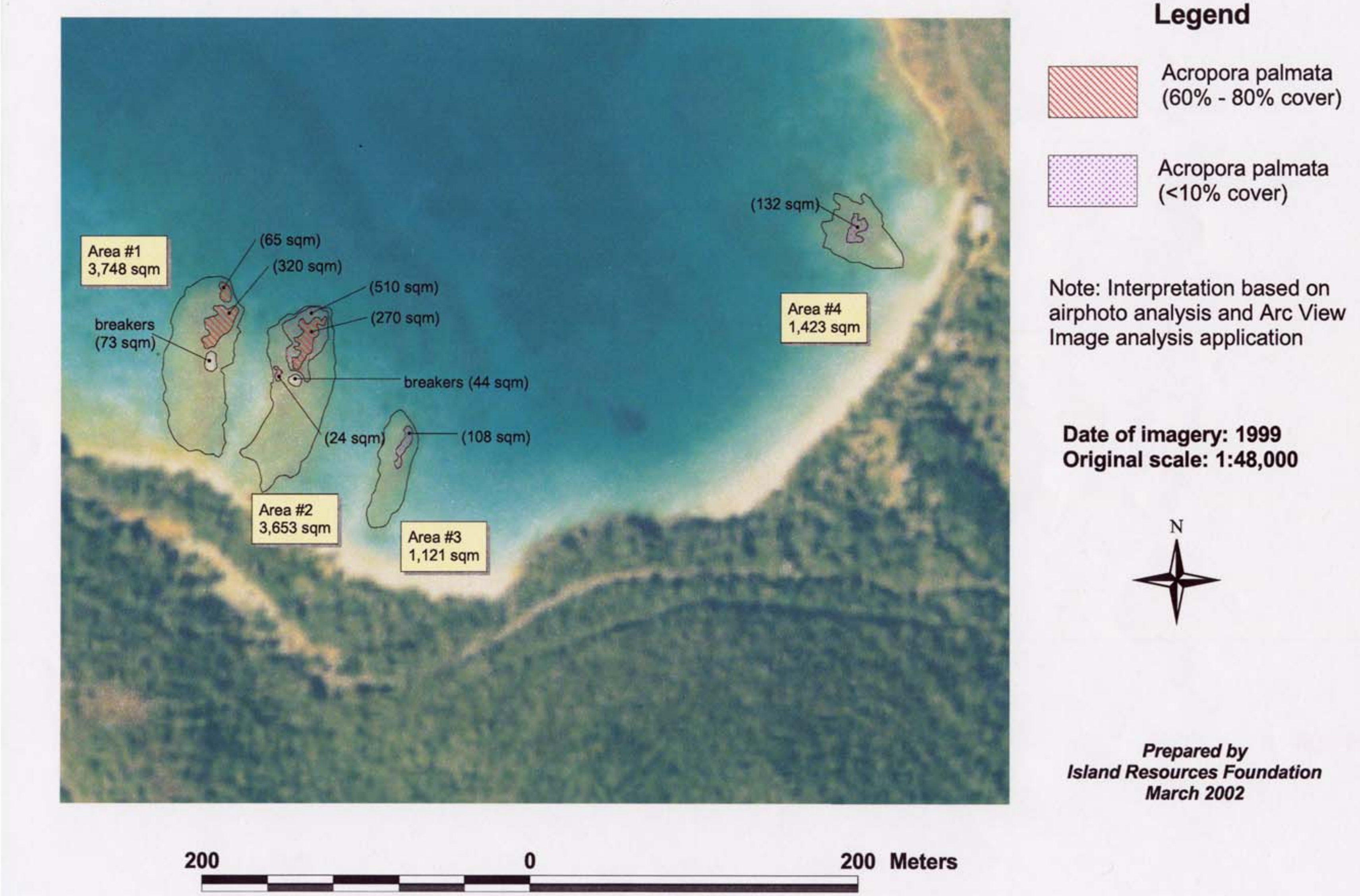


Figure #4: St. John / Windswept / 1974

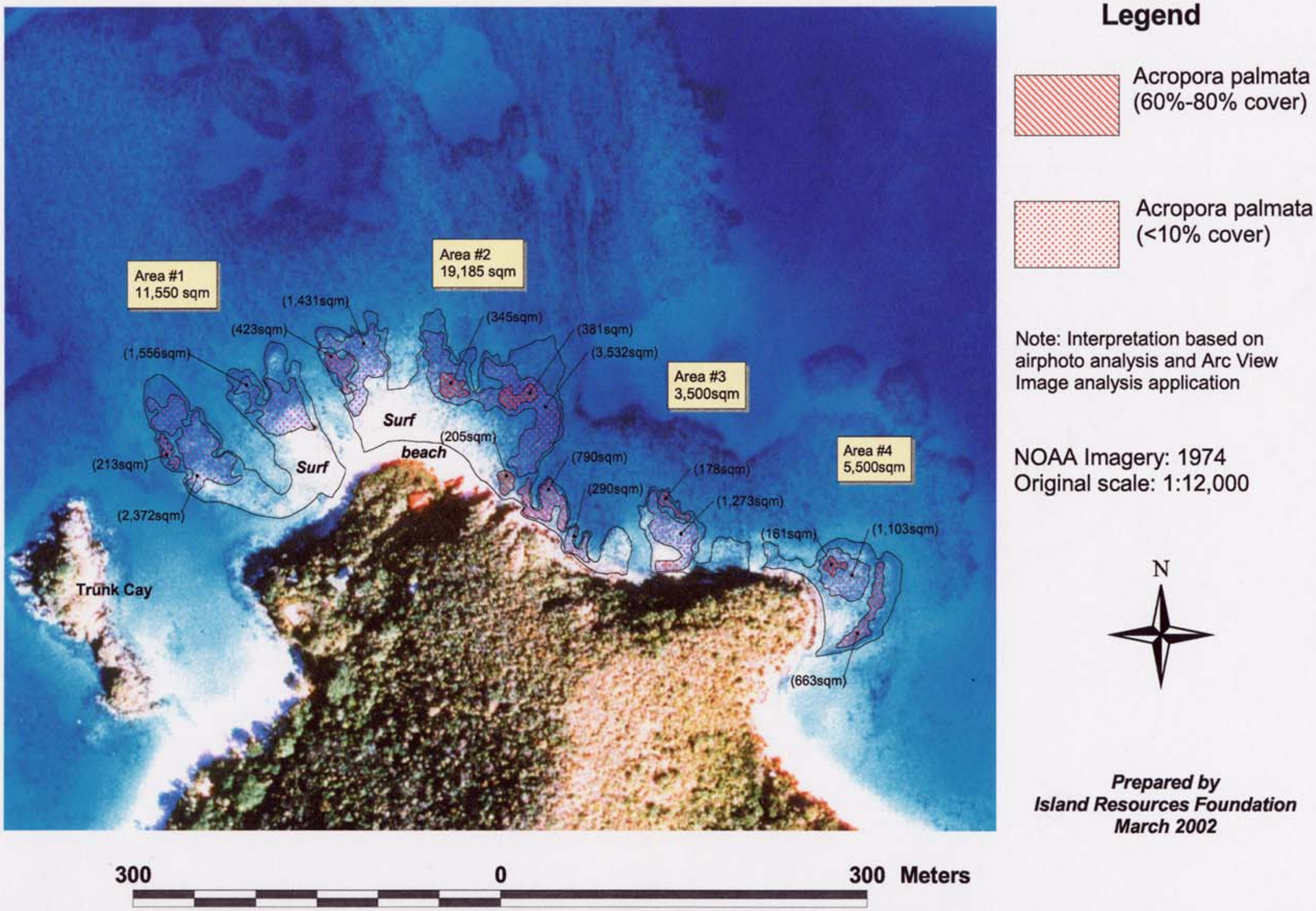


Figure #5: St. John / Windswept / 1983

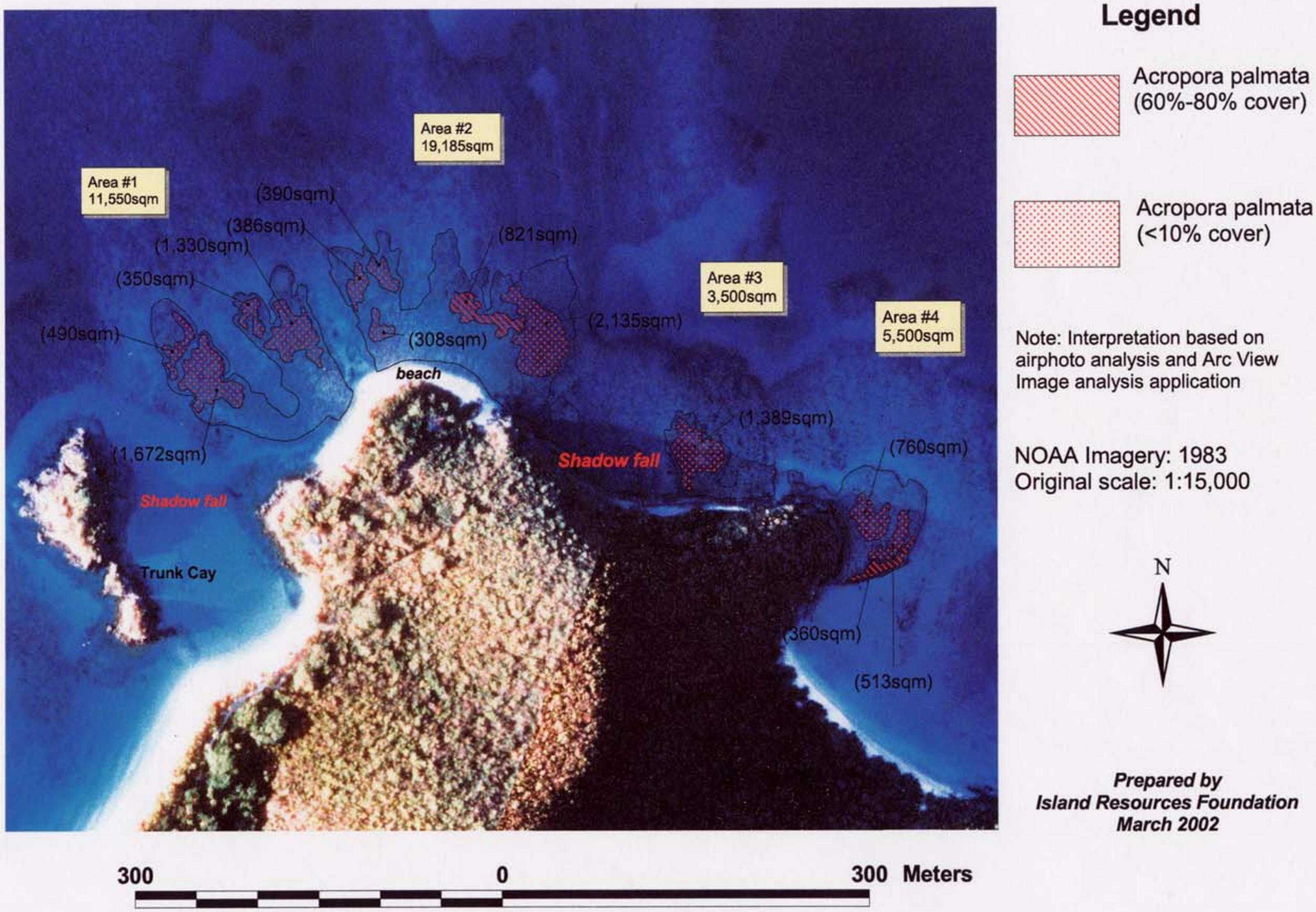


Figure #6: St. John / Windswept / 1999

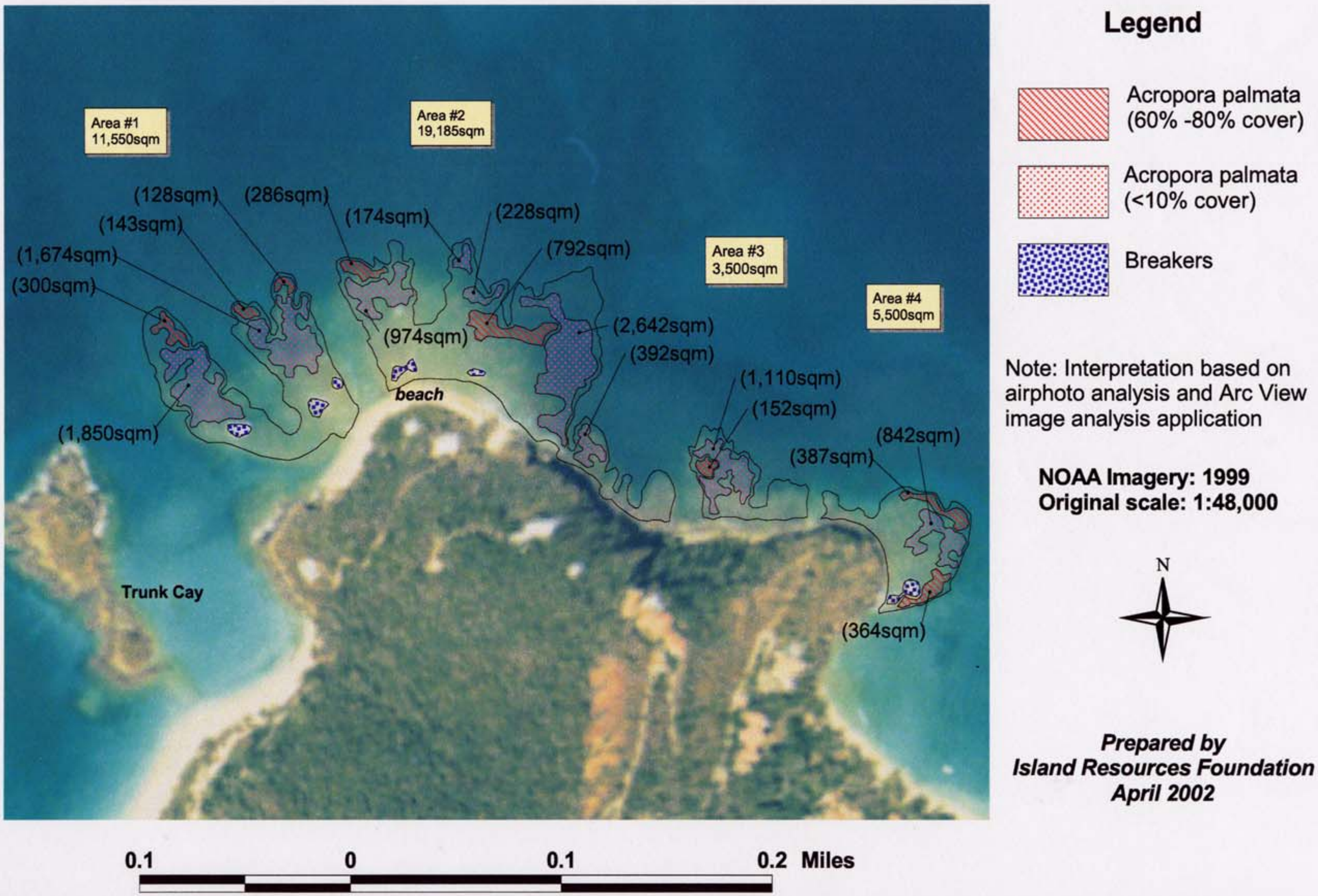


Figure #7: St. John / Haulover Bay / 1971

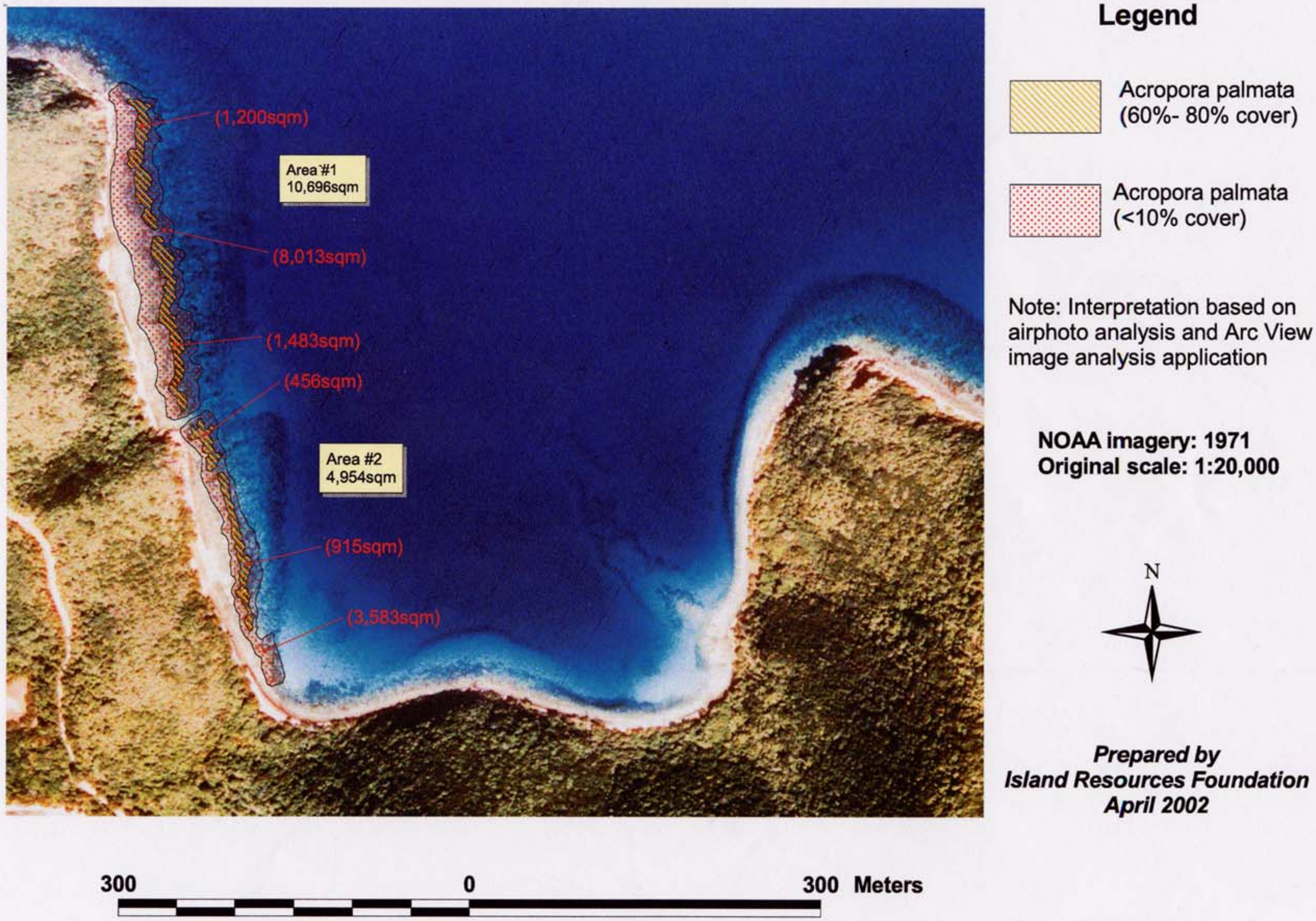
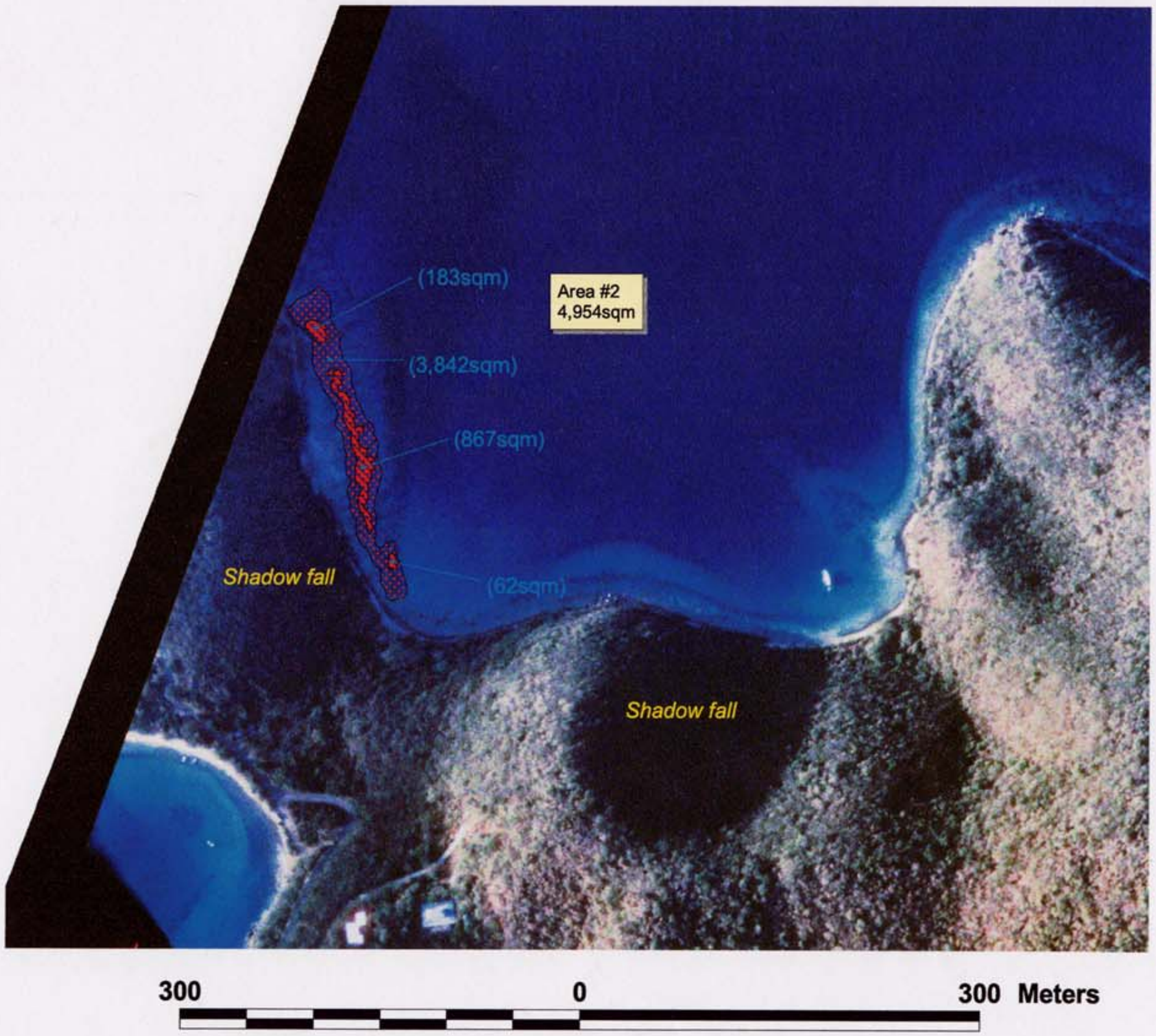


Figure #8: St. John / Haulover Bay / 1983



Legend

Acropora palmata (60% - 80% cover)

Acropora palmata (<10% cover)

Note: Interpretation based on airphoto analysis and Arc View image analysis application

NOAA imagery: 1983
Original scale: 1:15,000

N

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April 2002

Figure #9: St. John / Haulover Bay / 1999

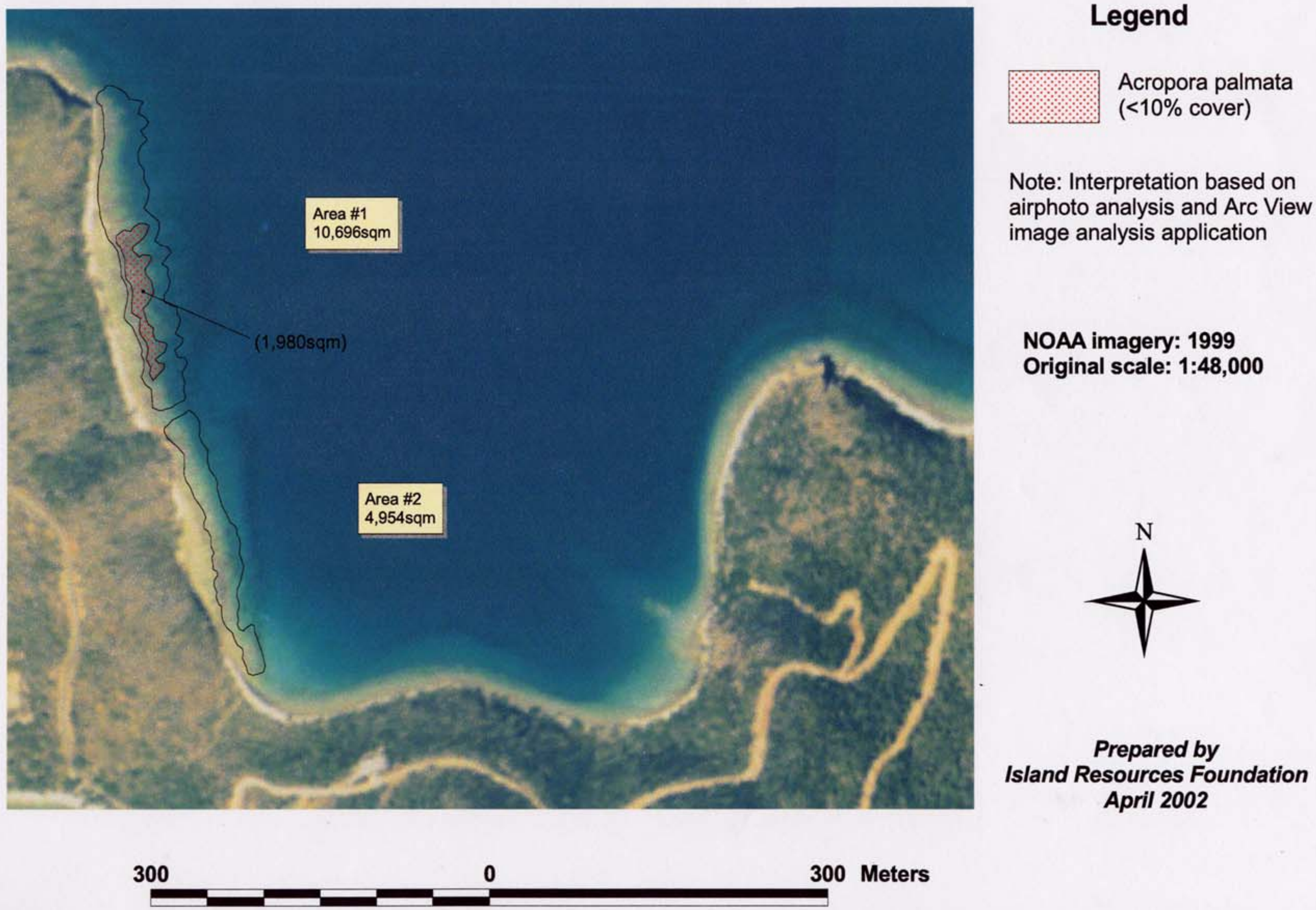
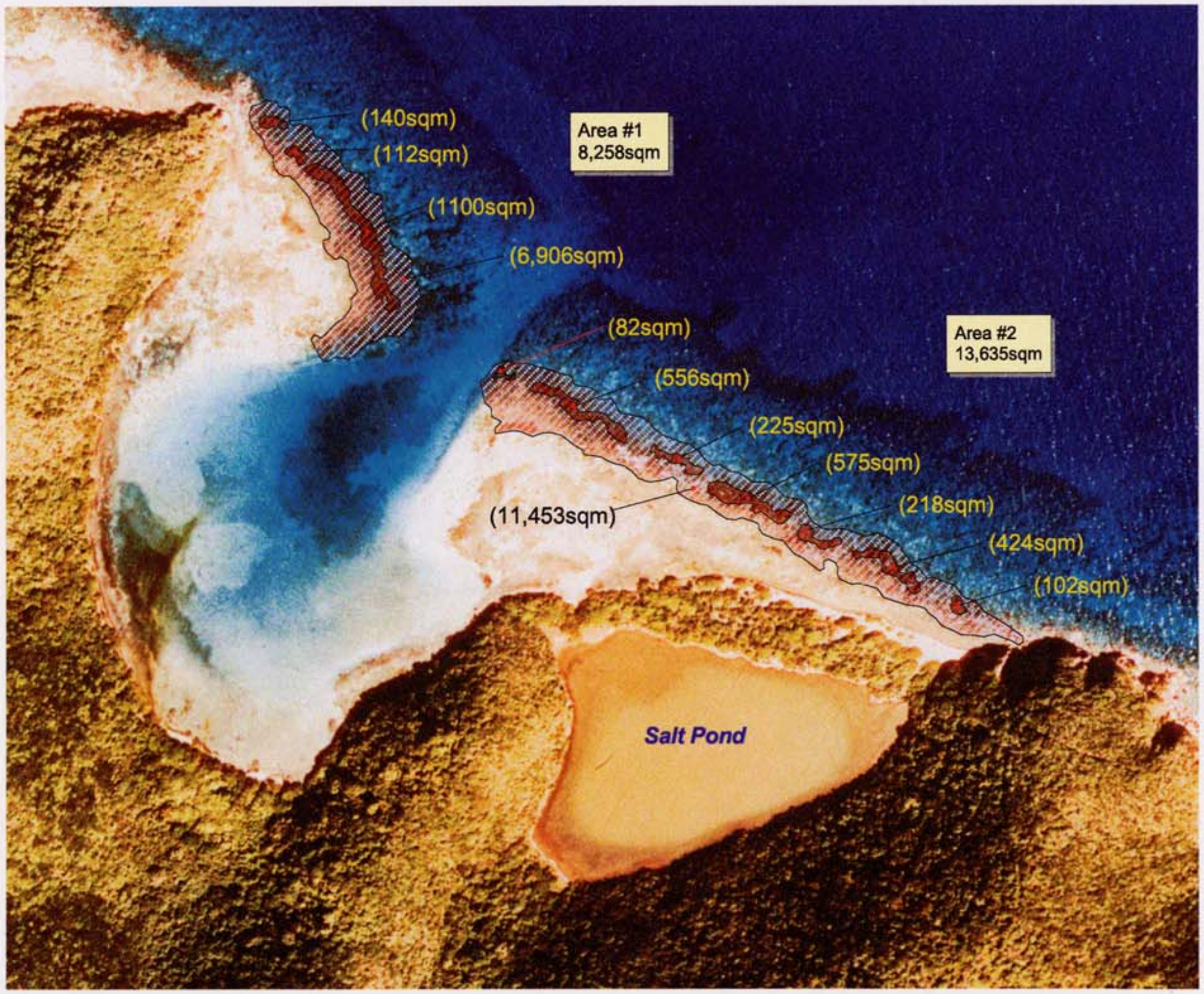


Figure #10: St. John / Newfound Bay / 1971



Legend

Acropora palmata (60% - 80% cover)

Acropora palmata (<10% cover)

Note: Interpretation based on airphoto analysis and Arc view image analysis application

NOAA imagery: 1971
Original scale: 1:20,000

N

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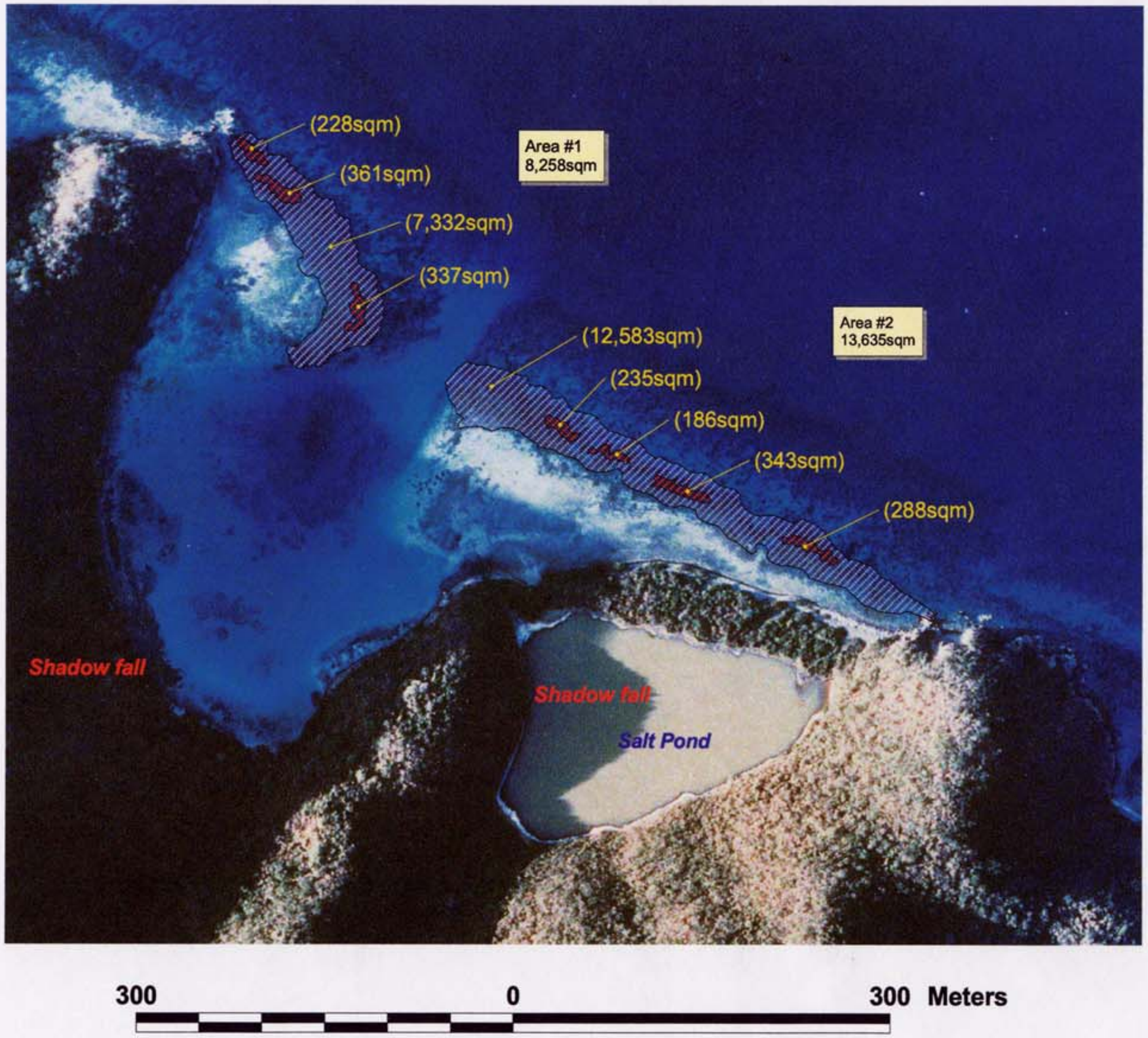
300 **0** **300 Meters**

Figure #11: St. John / Newfound Bay / 1983



Legend

Acropora palmata (60% - 80% cover)

Acropora palmata (<10% cover)

Note: Interpretation based on airphoto analysis and Arc View image analysis application

NOAA imagery: 1983
Original scale: 1:15,000

N

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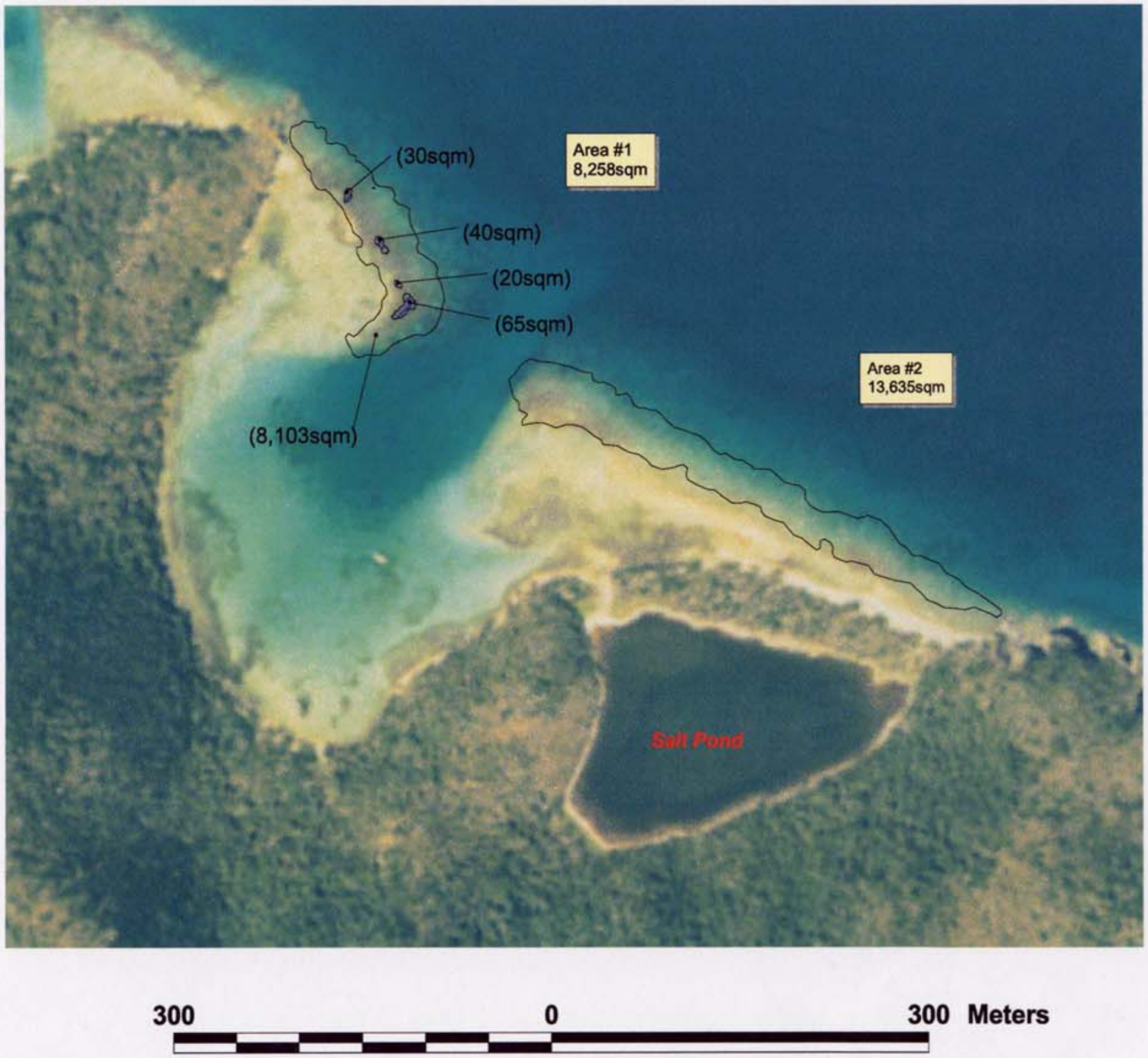
Figure #12: St. John / Newfound Bay / 1999



Legend

Acropora palmata (<10% cover)

Note: Interpretation based on airphoto analysis and Arc View image analysis application

NOAA imagery: 1999
Original scale: 1:48,000

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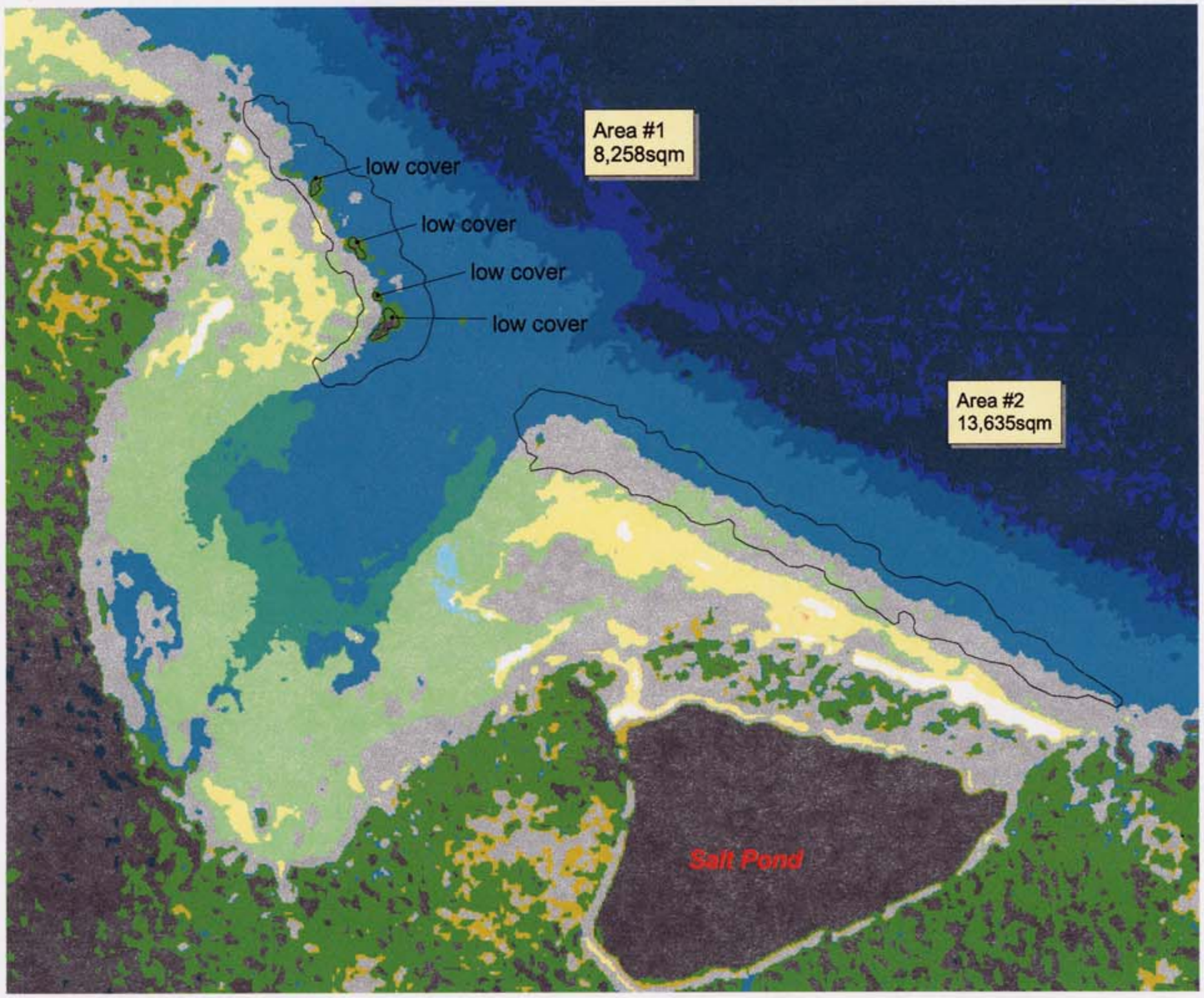
Figure #12a: St. John / Newfound Bay / 1999



Legend

Acropora palmata
low cover (<10%)

Arc view Image analysis
using "level slicing" tool

NOAA imagery: 1999
Original scale: 1:48,000

N

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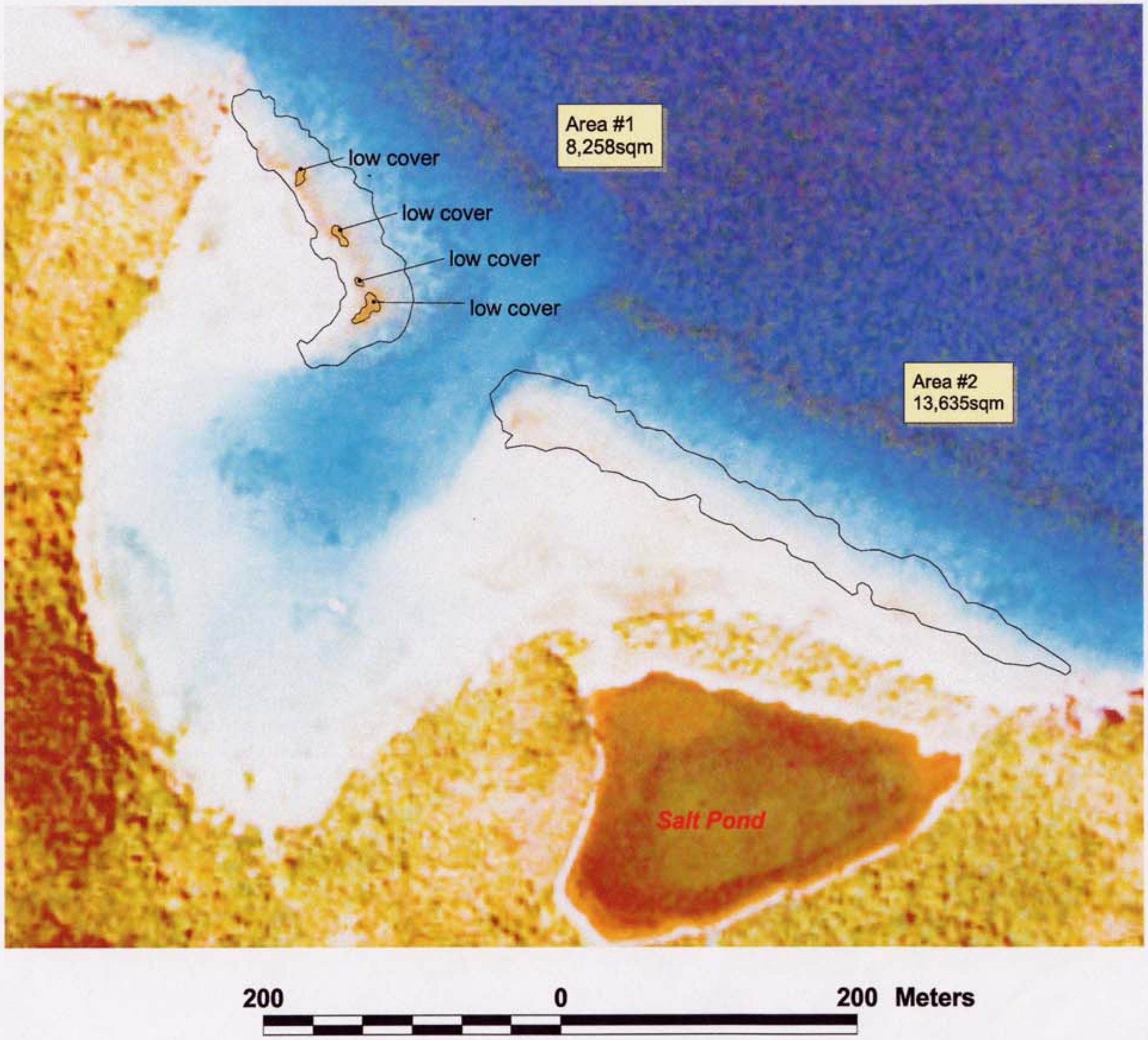
Island Resources Foundation
April 2002

200 0 200 Meters

Figure #12b: St. John / Newfound Bay / 1999



Legend

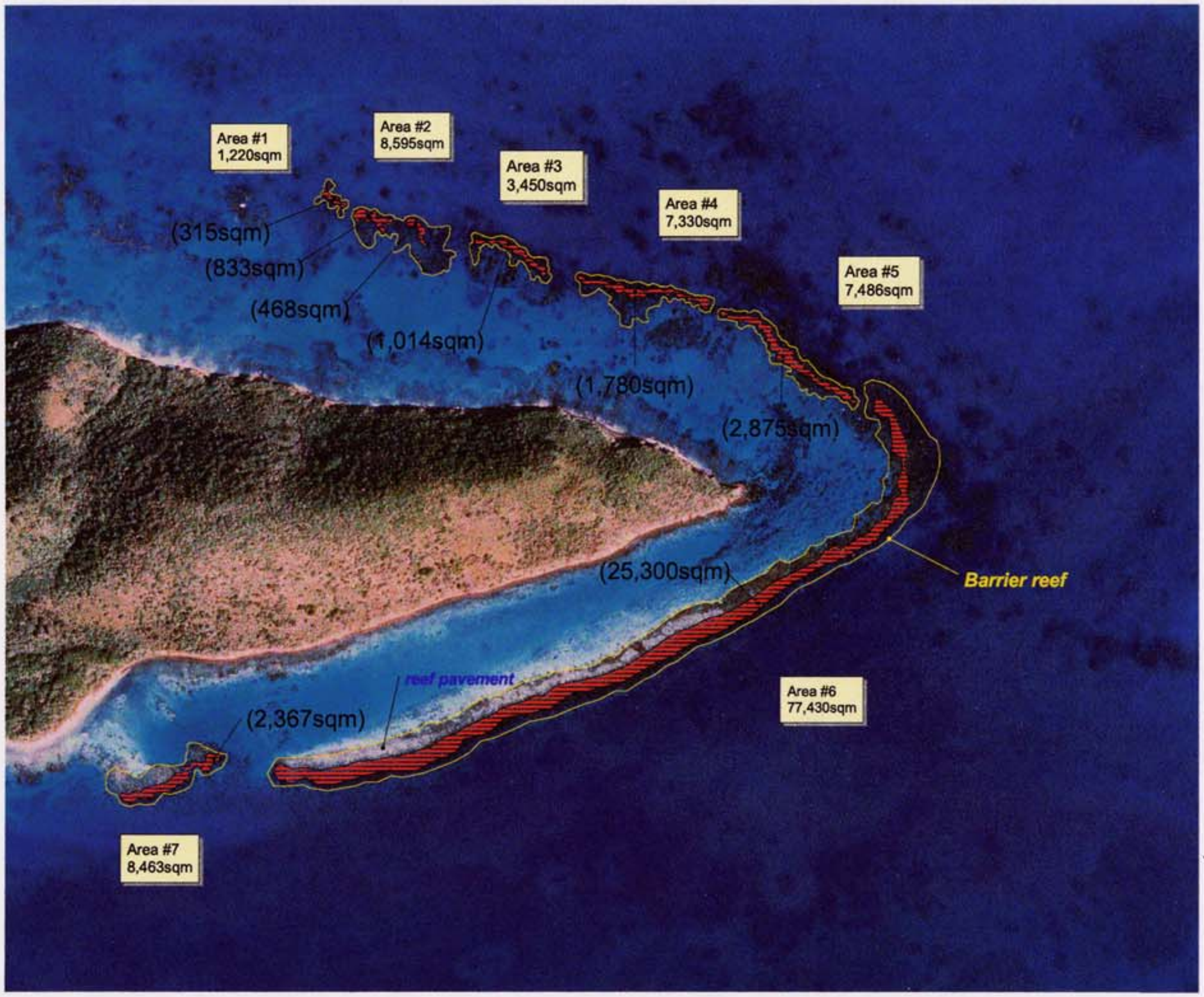
Acropora palmata
low cover (<10%)

Arc view Image analysis
using "Gaussian" tool
with higher contrast and
lower brightness

NOAA imagery: 1999
Original scale: 1:48,000

Prepared by
Island Resources Foundation
April 2002

Figure #13: St. Croix / Buck Island / 1977



Legend

Acropora palmata
(60% -80% cover)

Note: Interpretation based on airphoto analysis and Arc View image analysis application

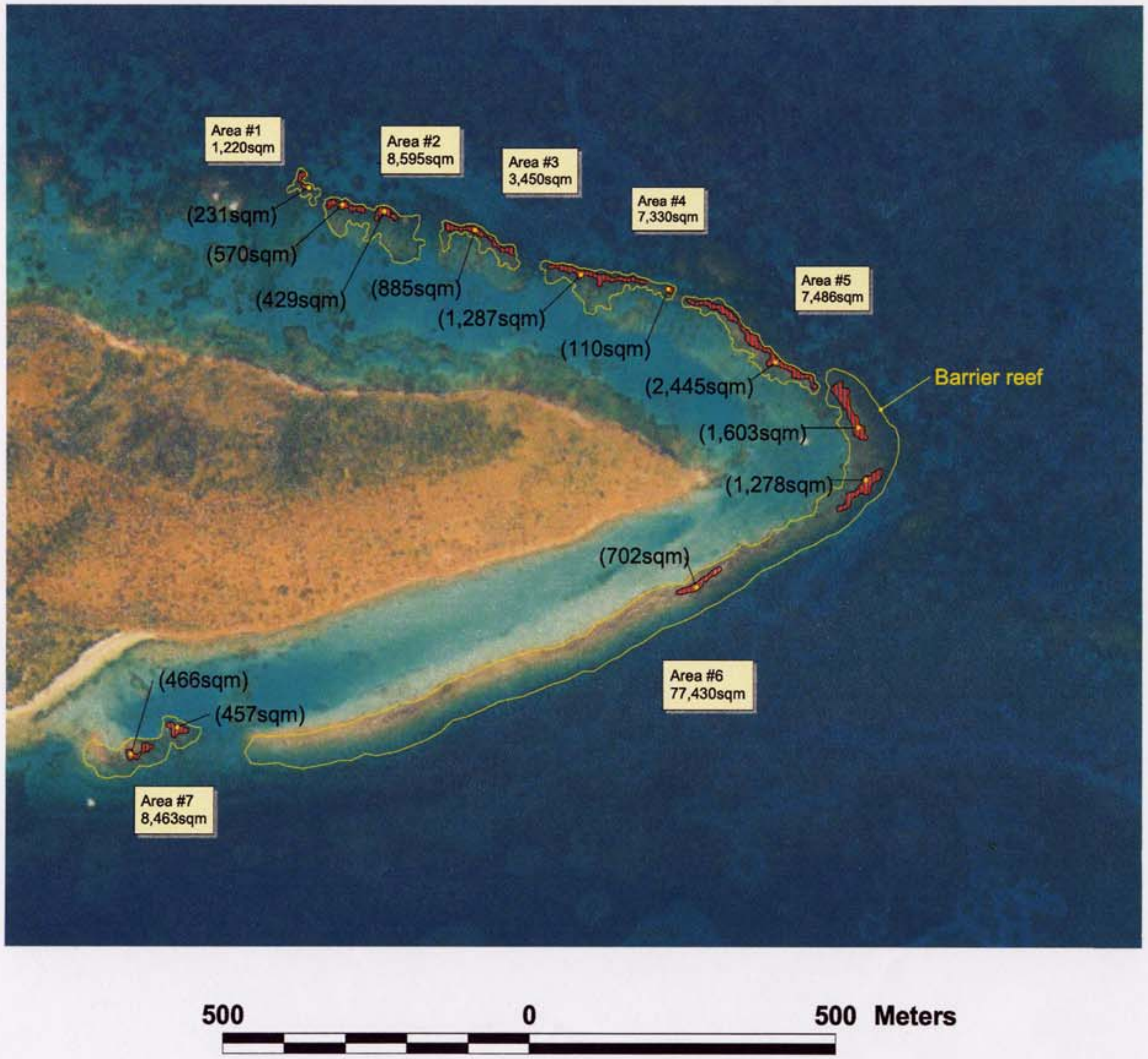
NOAA imagery: 1977
Original scale: 1:20,000

N

Prepared by
Island Resources Foundation
May 2002

500 0 500 Meters

Figure #14: St. Croix / Buck Island / 1999



Legend

Acropora palmata (< 10% cover)

Note: Interpretation based on airphoto analysis and Arc View image analysis application

NOAA imagery: 1999
Original scale : 1:48,000

N

Prepared by
Island Resources Foundation
May 2002